FINAL REPORT - SURFACE WASTE PILES SOURCE CONTROL DEMONSTRATION PROJECT

MINE WASTE TECHNOLOGY PROGRAM ACTIVITY III, PROJECT 10

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Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threatens human health and the environment. The focus of the Laboratory's research program is on methods and their cost effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments, and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. The NRMRL collaborates with both public and private-sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

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E. Timothy Oppelt, Director
National Risk Management Research Laboratory

Executive Summary

This final report was prepared for the Mine Waste Technology Program (MWTP) Activity III, Project 10, *Surface Waste Piles Source Control Demonstration Project*. The MWTP is funded by the U.S. Environmental Protection Agency (EPA) and jointly administered by the EPA and the U.S. Department of Energy. Project 10 addresses EPA's technical issue of *Mobile Toxic Constituents – Water* with a field demonstration at a remote, inactive mine. The objective of the technology demonstration was to show the effectiveness and feasibility of using a source control technology (i.e., stabilization material emplacement) that provides in situ stabilization/encapsulation resulting in the reduction and/or elimination of surface and shallow groundwater infiltrating into a surface waste pile. The stabilization material acts as a barrier system and reduces the generation of acid mine drainage (AMD) and decreases leaching of metals into surface water and groundwater.

In 1998, the MWTP selected the Peerless Mine as a demonstration site for field implementation and evaluation of the surface waste pile source control technology. Discharge from the Peerless Mine surface waste pile ranged from 2.6 to 22.6 gallons per minute of water containing dissolved concentrations of zinc, manganese, and cadmium at levels exceeding the National Drinking Water Maximum Contaminant Standards and was considered to be one of the main sources of pollution to nearby Banner Creek.

This document presents monitoring results, observations, and information for all three phases of this project and focuses primarily on the field emplacement, Phase III.

During Phase I, Mine Site Selection/Site Characterization, site hydrogeological background conditions were continuously monitored, and site geochemical measurements were collected on a monthly basis for 1 year. From these results, it was determined the Peerless Mine adit discharge infiltrates into the downgradient surface waste piles as the main source of groundwater flow. Additional sources of groundwater flow included flow from the adjacent losing streams, which flow on either side of the surface waste piles, and infiltration by precipitation. During site characterization, it was determined that surface water and groundwater contribute to the AMD problems at the Peerless Mine. As result, during Phase I, it was determined that a grout cover and a French drain system should be installed.

In Phase II, Materials Testing, the stabilization material, 4994 KOBAthane grout, was selected for the project. All candidate stabilization materials were evaluated for performance, durability, compatibility, applicability, and economic feasibility for the field demonstration at the Peerless Mine. These tests were performed by MSE Technology Applications, Inc., and an external laboratory. Each material was ranked as either passing or failing each test with three of the selected materials passing all tests. The 4994 KOBAthane grout was selected over the other two stabilization materials because it could be easily applied (spray-applied) onto the surface waste pile.

Phase III, Field Emplacement and Long-Term Monitoring, was performed to demonstrate the effectiveness of the stabilization material and the French drain system in preventing the formation of AMD by reducing infiltration of groundwater and surface water through the surface waste pile. The French drain system was constructed around the up-slope perimeter of the surface waste pile. The French drain was installed to reduce the amount of groundwater flowing through the surface waste pile. The drain acted as a hydraulic barrier, providing a preferential pathway and directing

groundwater flow away from the pile. The 4994 KOBAthane grout was spray applied onto the surface of the waste pile, reducing infiltration and shedding surface water downgradient. A high-density polyethylene liner was placed in a shallow ditch that was constructed around the base of the waste pile to act as a collection channel capturing surface runoff from the grout cover and directing the water away from the pile. Monitoring equipment was also installed at the end-point drainage locations from the French drain and the cap liner system.

The results of the long-term monitoring show that after emplacement of the French drain system and the 4994 KOBAthane grout cover, the water discharging from the toe of the surface waste pile no longer contained dissolved metals concentrations for zinc, copper, and cadmium that exceeded the National Drinking Water Maximum Contaminant Standards. The concentration of most of the dissolved metals in the discharge water flowing from the toe of the surface waste pile was approximately 2 to 4 times less than the measured readings before the technology emplacement at the Peerless Mine. However, dissolved metal concentrations of arsenic, iron, manganese, and silver did not change after the application of the technology. The iron and manganese dissolved metals concentrations increased. After reviewing the data, it was determined that the emplacement of the spray-applied cover caused a reducing environment to develop in the surface waste pile. Under reduced conditions and corresponding increased pH, metals such as copper, zinc, aluminum, and cadmium were precipitated. Other metals such as iron and manganese have increased solubility under these conditions and, as a result, dissolved iron and manganese concentrations increased.

Also during the demonstration, it was determined that the desirable characteristics of a spray-applied material include:

- the material can be applied at remote, steep, or inaccessible locations;
- the process requires minimal surface preparation;
- the material can be colored; and
- the material cures quickly and is flexible.

Additional testing of the spray-applied covers is now being performed.

This final report summarizes the results and illustrates effects of the work performed at the Peerless Mine site.

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Acronyms and Abbreviations

AMD	acid mine drainage
DOE	U.S. Department of Energy
E_H	oxidation-reduction potential
EPA	U.S. Environmental Protection Agency
HDPE	high-density polyethylene
IT	IT Geotechnical Laboratories, Inc.
LLDPE	linear low-density polyethylene
MCL	Maximum Contaminant Level
MSE	MSE Technology Applications, Inc.
MWTP	Mine Waste Technology Program
NPDWS	National Primary and Secondary Drinking Water Standards
QA	quality assurance
QAPP	quality assurance project plan

Acknowledgments

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1. Introduction

This document is the final report for the Mine Waste Technology Program (MWTP), Activity III, Project 10, *Surface Waste Piles Source Control Demonstration Project*. The MWTP is funded by the U.S. Environmental Protection Agency (EPA) and is jointly administered by the EPA and the U.S. Department of Energy (DOE) through an Interagency Agreement. Initially, this demonstration project consisted of developing a feasibility study to determine the applicability of innovative materials for in situ stabilization or encapsulation of a surface waste pile. In general, the final emplacement strategy of this project consisted of constructing an impervious barrier system at the selected demonstration site, the Peerless Mine, that would reduce and/or eliminate the influx of water through and into the surface waste pile. The primary objective of the demonstration was to reduce the generation of acid mine drainage (AMD) and decrease leaching of metals into the surface and groundwater, thereby reducing contaminant loading into nearby Banner Creek. This project was divided into three phases:

- Phase I, Mine Site Selection/Site Characterization
- Phase II, Materials Testing
- Phase III, Field Emplacement

During Phase I, the Peerless Mine was selected as the field demonstration site and was extensively characterized. Prominent features resulting from historic mining activities include surface waste piles that could be characterized as eroding, contaminated sediments, and discharging adits. The water from the mine site flows into the East Fork of Banner Creek, which is part of the water supply system for Helena, Montana. Additionally, AMD formed within the surface waste pile was affecting groundwater at the headwaters of Banner Creek.

During Phase II, MSE Technology Applications, Inc. (MSE) and IT Geotechnical Laboratories, Inc. (IT) tested approximately 50 materials to determine their compatibility, applicability, and economic feasibility.

Phase III involved installing two source control systems at the Peerless Mine site. First, a French drain system was placed around the up-slope perimeter of the surface waste pile to prevent groundwater seepage through the waste rock material. Secondly, to prevent surface water infiltration, a 4994 KOBAthane grout cover was spray applied on the pile. The goal of using both of these systems was to minimize the amount of water and oxygen penetrating into the surface waste pile, thus prohibiting the formation of AMD.

All work during Phase I and Phase III was performed under an EPA approved quality assurance project plan (QAPP). Phase II work was performed under a test plan but did not have any direct quality assurance (QA) oversight, although guidance was provided by the MSE QA department. The summary of QA activities for the project are provided in Appendix A.

This document provides generalized background information and results and observations from Phase I and II and provides a detailed description and final results of Phase III.

2. Phase I, Mine Site Selection/Site Characterization

In 1998, the MWTP selected the Peerless Mine as a demonstration site for the field implementation and evaluation for Activity III, Project 10 (Ref. 1). The Peerless Mine is located in Sec. 21 of T. 8 N., R. 5 W. in Lewis and Clark County and is located within the historic Rimini (also known as the Vaughan) Mining District (see Figure 2-1). The mine site is approximately 17 miles southwest of Helena, Montana, on the Banner Creek Road. Banner Creek, a tributary of Tenmile Creek, flows into Lake Helena, which is located at the headwaters of the Missouri River. Although the site is extensive, only the lower waste pile (referred to as WR2) at the site was targeted for this demonstration because it has distinct inflows and outflows (see Figure 2-2). The Peerless Mine adit discharge flows adjacent and through the surface waste rock piles (WR1 and WR2), exiting the toe of the surface waste piles and finally entering a small wetland area before draining into the East Fork of Banner Creek (see Figure 2-2).

The Peerless Mine is an inactive mine site with associated surface waste piles located in the Banner Creek drainage. Hazards at the mine site include two collapsed adits, a shaft, two surface waste piles, a loadout chute, and housing structures (see Figure 2-2). The total volume of waste rock in the lower waste pile (WR2) is estimated at less than 10,000 cubic yards (yd^3) (Ref. 2). A smaller surface waste pile (WR1) lies just south of WR2 and has an estimated volume of 3,800 yd^3.

The Peerless Mine had heavy metal-laden contaminated water discharging from the adit and the toe of the two surface waste piles located at the north end of the site. Heavy metals are the main contaminants at these two point-source discharge locations. Available data suggest that metals concentrations did not exceed Maximum Contaminant Levels (MCLs) as defined by the National Primary and Secondary Drinking Water Standards (NPDWS) at the adit. Discharge from the Peerless Mine adit formed a small wetland area located on the uphill side of WR1, and water from the wetland area infiltrated through and around that pile (see Appendix B). The quality of the water flowing into and out of WR1 did not exceed the National Drinking Water Maximum Contaminant Standards. However, after contacting WR2, the surface waters became acidic and laden with heavy metals and exceeded the set regulatory standards.

Water discharging from the toe of WR2 was considered to be a main source of pollution to Banner Creek. Water discharging from WR2 ranged from 2.6 to 22.6 gallons per minute (gpm); had a pH ranging from 3 to 4; and contained zinc, manganese, and cadmium at levels exceeding the National Drinking Water Maximum Contaminant Standards.

The main purpose for characterizing the Peerless Mine site, especially the surface waste piles, was to 1) provide baseline information, 2) determine where the inflow and outflow of water into the surface waste piles occur, and 3) determine the mechanisms controlling these flows (Ref. 1). Continuous flow monitoring stations (weirs) and monitoring wells were installed at locations shown in Figure 2-2 and in Appendix A (W-1 signifies weir 1, and MW-1 signifies monitoring well 1). During site characterization, hydrogeological, geological, and water quality information was collected and evaluated to define the source control technologies and emplacement methods that could be used to reduce, eliminate, or treat flows in and out of the surface waste pile (Ref. 3). Historical data from the site were used to supplement the data collected during site characterization.

To characterize the site and determine the sources of AMD in Banner Creek, water sampling of the identified flows was performed for 1 year. The results of this sampling indicated that flow from the adit and around WR1 had dissolved metals concentrations less than the National Drinking Water MCLs.

From site characterization results, it was determined that the adit discharge from the Peerless Mine infiltrates into the surface waste piles and is the main source of groundwater flow (Ref. 1). However, other contributions to groundwater flow within the piles included recharge or water influx from the adjacent streams located on either side of the surface waste piles and precipitation infiltration.

Localized precipitation (rain) and the Peerless Mine adit discharge have a pH of approximately 7 and do not carry large percentages of heavy metals or suspended solids. When mine adit discharge and precipitation travel across and infiltrate the surface waste piles, these waters became exposed to oxygen and sulfide ore and form AMD. To reduce and/or eliminate water from infiltrating through the voids (hydraulic connections) in the surface waste pile, this demonstration placed stabilization materials in the form of an impervious, spray-applied cover over the lower surface waste pile (WR2) to eliminate infiltration.

Additionally, to reduce groundwater flow under the surface waste pile, a French drain was constructed and used to divert the groundwater away from the waste material.

From the results of the site characterization, it was determined that surface water and groundwater contribute to the AMD problems at the Peerless Mine. As a result of this finding, a multiphase solution was used for the field demonstration.

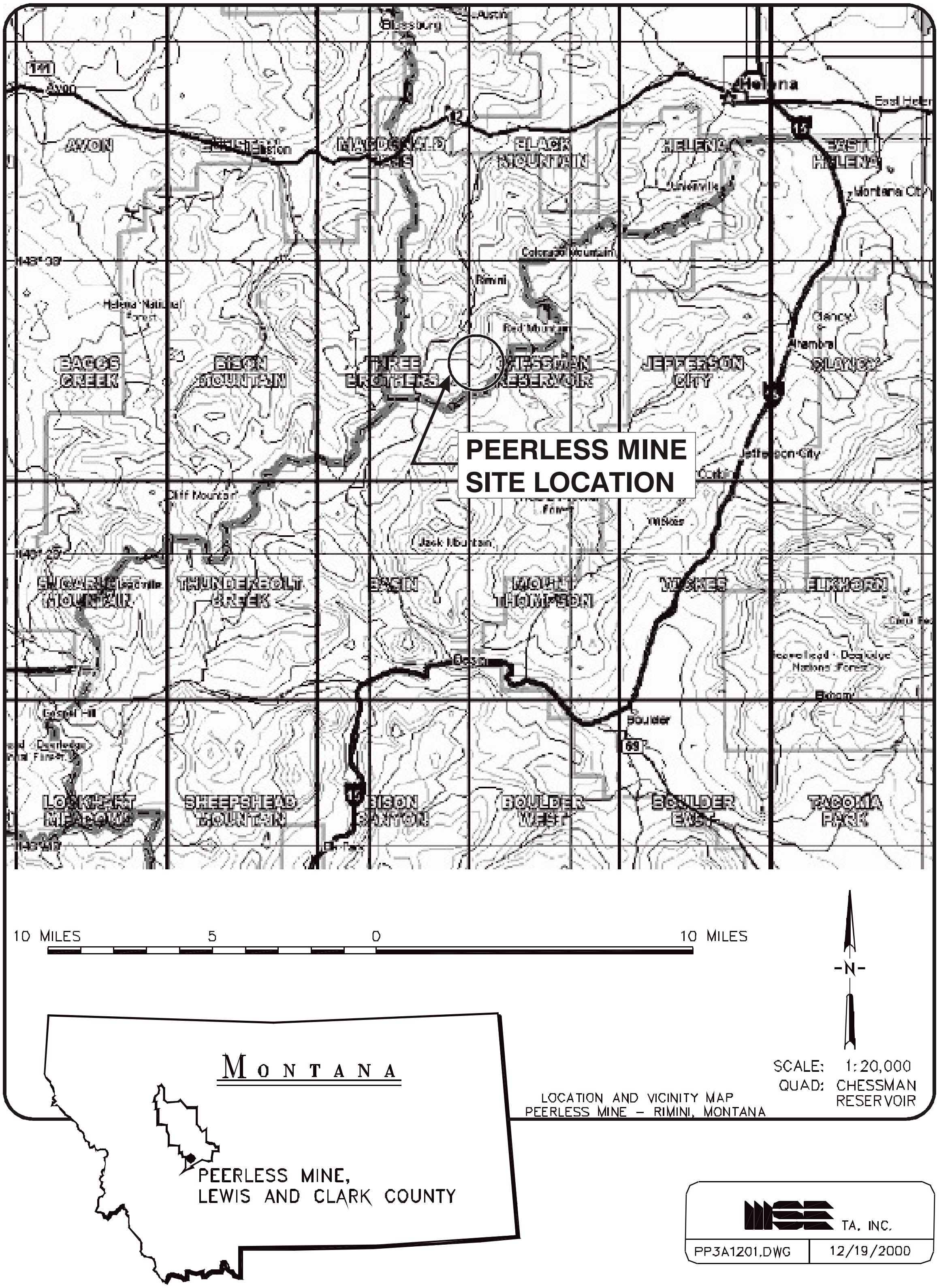

Figure 2-1. Peerless Mine site location map.

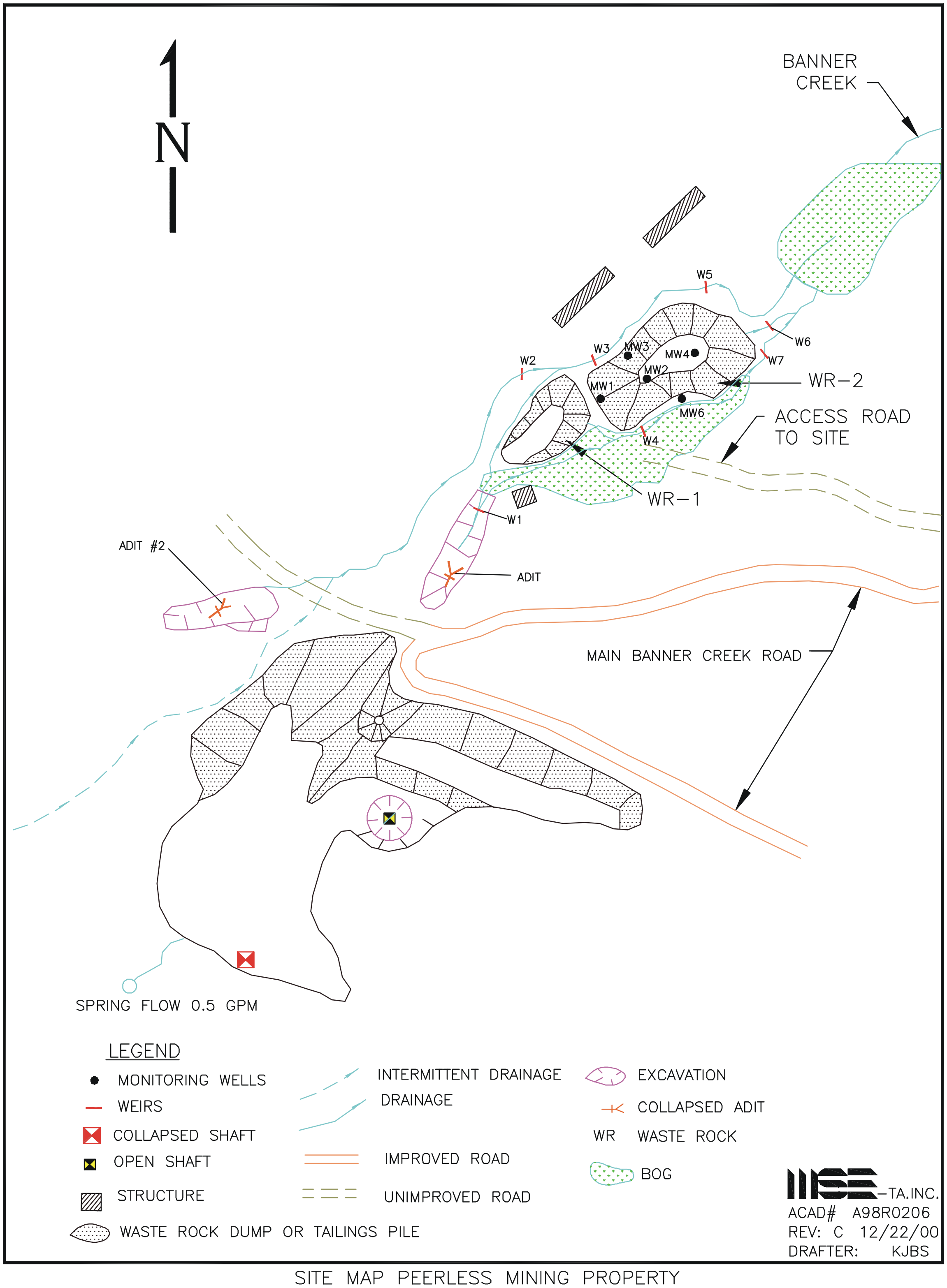

Figure 2-2. Peerless mining property site map.

3. Phase II, Materials Testing

The overall purpose of Phase II testing was to select a source control material for in situ stabilization/encapsulation of a surface waste pile (Ref. 4). Phase II evaluated and compared approximately 50 different stabilization materials. The objective of the materials testing was to provide a rational set of measurements and results by which a stabilization material could be selected for the demonstration. Initial feasibility of potential stabilization materials was determined in the laboratory using the selected tests described in Reference 1, and final feasibility was determined using small field tests at the selected site using specified success criteria.

Although many of the material tests were specific to the surface waste rock materials, the tests were general enough that they could be modified for application at any mine site with similar problems. Ultimately, the performance goals defined for a specific site determine which tests are required to determine the feasibility of a potential stabilization material.

Primary success criteria established for selecting potential stabilization materials included:

- the material needed to be environmentally benign;
- the cured material must achieve a hydraulic conductivity when mixed with the mine waste materials of 10^{-6} centimeters per second;
- the cured material was able to withstand acidic mine water having a pH of 3 for an extended period of time;
- the material could be applied in a field demonstration; and
- the material was cost effective when compared to the standard reclamation procedures and technologies.

The secondary success criteria for the potential stabilization materials were that the materials could withstand both wet-dry cycling and freeze-thaw cycling tests for 12 cycles while maintaining less than 50% material loss over the duration of the testing. The stabilization materials were evaluated for performance, durability, applicability, and economics for the field demonstration.

The material tests were performed by MSE and IT Laboratories, and the results were evaluated against the success criteria. Each material was rated as either passing or failing each test. After the results were evaluated, only three materials passed all the material tests. The final materials then underwent preliminary field testing to establish final application and cost parameters. The 4994 KOBAthane grout was selected as the stabilization material.

4. Phase III, Field Emplacement

Field emplacement was performed during October and November 1999 at the Peerless Mine. A multiphase solution to the AMD problems at the Peerless Mine was incorporated for the field demonstration as a result of site characterization, which determined that both surface water and groundwater contributed to AMD production (see Figure 4-1). The multiphase solution included constructing a French drain system to reduce groundwater infiltration through the surface waste pile (WR2) (i.e., working as a hydraulic barrier) and spray applying 4994 KOBAthane grout (the stabilization material) over the surface as an impervious barrier to prevent precipitation infiltration. Extra monitoring equipment and a surface water collection channel were installed to complete the field demonstration.

4.1 French Drain System

A French drain system was constructed as a hydraulic barrier. This drain was designed to provide a zone of increased hydraulic conductivity for conveyance of groundwater away from WR2. As a result, the volume of groundwater flowing beneath this surface waste pile was reduced (see Appendix A and Figure 4-1). The French drain construction involved 1) excavating a 420-foot by 4-foot-wide trench around the uphill perimeter of WR2; 2) installing 420 feet of 6-inch, slotted, high-density polyethylene (HDPE) pipe wrapped with geotextile filter cloth bedded with 1-1/2-inch minus washed gravel; 3) installing to surface grade 6-inch minus, screened river-run, riprap over the bedding material and filled to the top of the trench; and 4) installing two concrete end plugs to anchor the wrapped pipe and to facilitate the connection of the slotted pipe to 200 additional feet of smooth bore, 6-inch HDPE solid discharge pipe (see Appendix B).

4.1.1 French Drain Trench Construction

To install the French drain system (see Figure 4-2), a trench was constructed around the uphill perimeter, encompassing three-quarters of the surface waste pile. Excavation of the trench began on the downhill end of the surface waste pile and continued uphill along both sides of the pile until the two trenches were joined at the head of the pile. Design excavation depth was 10 feet below ground surface unless bedrock was encountered. In most instances, bedrock contact was made before the design depth was achieved; therefore, the average depth of the ditch was 5 feet. Material excavated from the ditch consisted of sandy material mixed with large boulders. This material was placed on the surface waste pile for use during construction of the liner system. To prevent the excavated material from falling into the trench, the French drain was constructed approximately 4 feet from the base of the surface waste pile, forming a natural channel for surface runoff precipitation from the cover.

4.1.2 Concrete Plugs

A concrete plug, 4 feet wide by 4 feet long by 5 feet deep, was placed in each end of the horseshoe-shaped trench to prevent unwanted discharge. A coupler was cemented inside the plug 6 inches from the bottom of the trench to allow the water to pass through. This coupler was used as a connector between the perforated pipe placed in the trench and the solid discharge pipe routed to the surface.

4.1.3 Piping

To convey groundwater away from the pile, 420 feet of 6-inch, slotted, HDPE pipe wrapped with geotextile filter cloth was placed in the trench. This pipe was installed on a 6-inch bed of 1-1/2-inch minus gravel. The pipe traveled from the head of the pile, down both sides, and connected to the coupler embedded in the concrete plug. An additional 6 inches of

1-1/2-inch minus gravel was then placed on top of the pipe as a cover followed by 6-inch minus river-run riprap to the top of the trench. Finally, on both sides of the surface waste pile, 100 feet of smooth bore HDPE drainpipe was connected to the discharge side of the concrete plug.

4.1.4 Gravel

A 6-inch minus, screened river-run, riprap gravel was used to fill the trench. Enough material was brought to the site to match the original surface topography. The purpose of using the gravel was to provide an area of increased hydraulic conductivity, which provided a preferential flow path for surface water and groundwater, resulting in a hydraulic barrier. As the water flowed downgradient through the gravel, it was directed into the slotted discharge pipe. Since the surface waste pile had a lower hydraulic conductivity than the French drain, most of the water flowed through the French drain and did not enter the surface waste pile.

4.2 Surface Cover

General Polymers 4994 KOBAthane grout was spray applied onto the pile to prevent infiltration of precipitation (see Figure 4-3). This grout is a two-component aromatic membrane, urethane. Approximately 930 gallons of 4994 KOBAthane grout were applied, which covered an area of 16,828 square feet. After applying the grout, the pile was covered with a heavy woven jute and burlap material. A surface water drainage ditch and collection channel were constructed at the base of the grout cover to gather runoff precipitation and direct water away from the pile. The channel dimensions were approximately 640 feet long by 6 feet wide by 2 feet deep. A 40-millimeter (mm) linear low-density polyethylene (LLDPE) liner was used to line the channel. The liner was tied into the surface waste pile underlying the grout cover to prevent seepage into the pile at the seam.

4.2.1 Lined Collection Channel

The collection channel was constructed using the excavated material obtained during construction of the French drain. This excavated material was placed at the base of the waste pile to form a drainage ditch. Once all material from the French drain excavation was in place, channel smoothing began in which large boulders were removed to create a smooth, even bottom. This was necessary to prevent puncturing the liner and to create a preferential flow path for runoff precipitation.

To prevent water seepage into the surface waste pile, a 40-mm, LLDPE liner was installed along the surface water collection channel (see Figure 4-4). The liner was received as a single 8-foot-wide by 688-foot-long roll. To place the liner in the ditch, the liner had to be spliced in several places and welded together. Sections of approximately 50 feet were cut from the roll and were placed in the collection channel. Each section was then aligned with the previous section end and welded together to create a leakproof seam. This continued until the collection channel was completely lined with the LLDPE. Next, a small 6-inch ditch was constructed along the upper edge of the liner for a tieback. The liner was then placed into the ditch and covered with material from the waste pile. The other edge of the liner was draped over the lower edge of the collection channel and was secured in place using the same method that was used for the upper edge of the channel. The collection channel completely encircled the surface waste pile. At the downhill side of the surface waste pile, a discharge outlet was constructed to allow the runoff precipitation to be measured and then transported away from the surface waste pile.

4.2.2 4994 KOBAthane Grout Cover

The 4994 KOBAthane grout was used as the impervious cover for the surface waste pile. This grout is a two-component chemical grout material that is available in 5-gallon buckets. In order for the material to be spray applied, a pump-and-spray nozzle system was used. The material was mixed using a 1:1 ratio of catalyst to grout. The temperature at the time of application was approximately 40 EF. As a result, the grout was extremely viscous, having a consistency similar to glue, which made application difficult. However, after trying several different pumping and spraying systems, the material was successfully applied using a diesel-powered, triplex Bean pump. Application began at the top of the pile and continued down the slope to the base of the pile. The pile was divided into 100 square foot sections to ensure the pile was uniformly covered with the grout (see Figure 4-5).

The initial cover was constructed by spraying the 4994 KOBAthane grout directly on WR2 (see Figure 4-6). However, after half of the pile was covered, it was determined that spraying directly onto the surface resulted in too much product being used, and the grout was not being applied as uniformly as desired. A 1/8-inch webbed, jute material was placed on the pile, and the grout was applied on several final test areas to reduce the amount of grout applied. The spray application improved with respect to uniformity and adherence in the areas were the jute material was placed.

To prevent damage to the grout cover, an additional 3/4-inch webbed, jute material was applied to the pile (see Figure 4-7). This jute material was secured at the top and then rolled down each side. The jute material was overlapped 1 foot on both sides of each section to ensure the pile was completely covered. The initial project design specified that seeded topsoil be placed on top of the jute (see Figure 4-8). However, the seeded topsoil cover was eliminated because the surface waste piles at the Peerless Mine were to be removed under a Time Critical Removal Action by EPA, Region 8.

4.3 Additional Monitoring Equipment

Additional monitoring equipment (three extra-large 60-degree trapezoidal flumes) was installed to monitor two distinct outflows from the French drain system and the flow from the collection channel. Reflectometers were installed to monitor the moisture content of a background surface waste pile (WR1) and the surface waste pile (WR2) covered with 4994 KOBAthane grout to determine if the cover was effective in eliminating infiltration.

4.3.1 Flumes

The three extra-large 60-degree trapezoidal flumes were purchased from Plasti-Fab, Inc. to measure the flow rates from the French drain and the collection channel. In order to record accurate flow rates from the French drain and the collection channel, the flumes had to be level. To level and stabilize the flumes, preliminary groundwork was completed, and the flumes were set on 4-inch by 4-inch treated lumber sets and secured to the ground surface with concrete. The flume attached to the collection channel was connected to the LLDPE liner at the toe of the surface waste pile by inserting the liner into the flume and securing it using bolts and silicone sealer. Water discharging from the French drain was directed to the two additional flumes using the smooth bore HDPE solid drainpipe mentioned in Section 4.1.3. This pipe was connected to the two flumes using a rubber boot adapter that fit over the end of pipe and flume inlet. The water was then directed through the sediment control structure from the flumes and allowed to flow down to Banner Creek, preventing any backup of surface water or groundwater.

4.3.2 *Reflectometers*

Two reflectometers were installed to measure moisture content of the surface waste pile material. Reflectometer RF1 provided background measurements and was placed in the upper waste pile, WR1, which did not have an impervious grout cover. Reflectometer RF2 was placed in the surface waste pile, WR2, which was covered by the spray-applied 4994 KOBAthane grout material (see Appendix B). These reflectometers were placed into the soil at a depth of 1 foot below ground surface. Data from the reflectometers were continuously monitored and stored in a data logger.

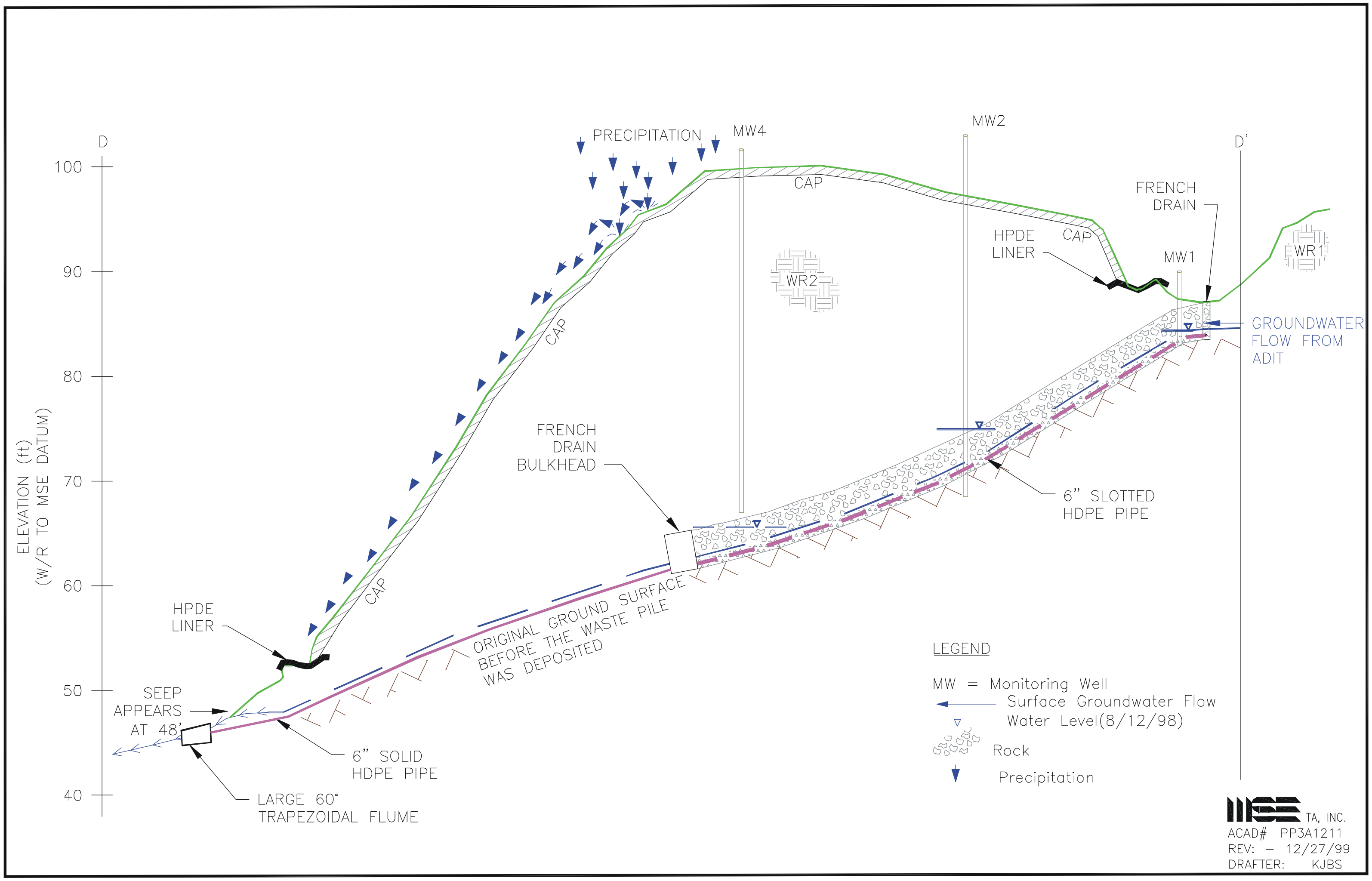

Figure 4-1. Cross section of surface waste pile (WR2) with installed French drain and grout cover (not to scale).

Figure 4-2. The French drain trench with the 6-inch slotted HDPE pipe wrapped in geotextile and partially covered with 1-1/2-inch minus gravel.

Figure 4-3. 4994 KOBAthane grout being applied directly onto the surface waste pile (without a jute layer).

Figure 4-4. Surface water drainage ditch and collection channel with LLDPE liner and the surface waste pile covered with the final jute layer.

Figure 4-5. Division of the surface waste pile into 100 square foot sections for spray application of grout.

Figure 4-6. Spraying grout directly onto the surface waste pile without the jute material.


Figure 4-7. Jute material applied to the surface waste pile.

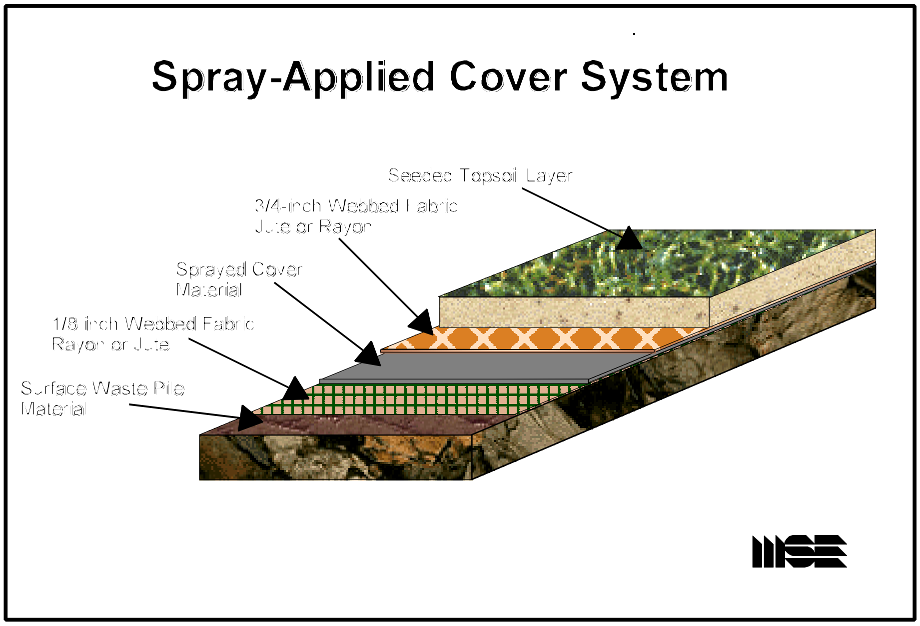

Figure 4-8. Conceptual design for emplacing a spray-applied cover system to a surface waste pile.

5. Project Results

This section presents the monitoring results and observations and compares data collected before and after the grout cover and French drain systems were constructed at the Peerless Mine. The results are shown in an order representing the actual downgradient flow path at the site.

5.1 Groundwater Results

The groundwater results include data collected at monitoring wells MW1, 1A, 2, 3, 4, 6, and 7 and flumes 1 and 2 (F1 and F2) (see Figure 2-2). The monitoring wells were constructed and located upgradient and downgradient of the French drain system in the surface waste pile (WR2) and intersect the groundwater table under the surface waste pile (see Figure 4-1). The flumes were located downgradient of the surface waste pile and were used to monitor water quality and the discharge collected from the French drain.

5.1.1 Monitoring Well 7

Monitoring well 7 (MW7) was located at the toe of the upper surface pile (WR1) just upgradient of the French drain system (see Appendix B). MW7 was an upgradient, background well installed in May 2000, and results for MW7 were collected on a monthly basis for 3 months (May, June, and July 2000). The pH remained constant through these months, ranging between 5.6 to 5.2. The static water level in the well showed a decrease of 0.50 foot, primarily due to seasonal groundwater level fluctuations. Metal concentrations in MW7 varied due to seasonal fluctuations, see Appendix C.

5.1.2 Monitoring Well 1 and 1A

Monitoring well 1 (MW1) was located at the head or upgradient side of WR2 (see Figure 4-1). Data collection from MW1 began in September 1998 and concluded in September 1999 when the well was removed during construction of the French drain. In November 1999, another monitoring well, MW1A, was placed just downgradient of the French drain system but on the upgradient side of WR2. MW1A was used to observe fluctuations in the groundwater table and take water quality samples.

The pH for MW1 ranged from 5.1 to 7.8. Changes in pH were primarily due to seasonal fluctuations of groundwater near the well. The pH for MW1A, after the technologies were applied, ranged from 5.6 to 8.6. Due to the minimal length of time that MW1A was monitored (November 1999 to August 2000), it was not apparent if fluctuations in pH as well as some dissolved metals were due to the seasonal variations or the changed location of the well (see Appendix C).

5.1.3 Monitoring Well 2

Monitoring Well 2 (MW2) was located in WR2 on the upgradient side of the pile (Figures 2-2 and 4-1). Data collection from MW2 began in September 1998 and concluded in July 2000. Parameters that were measured included pH, oxidation-reduction potential (E_H), and concentration of dissolved metals. The pH at MW2 ranged from 5.6 to 6.6 prior to technology implementation. This variation was assumed to be due to seasonal fluctuations in level and quantity of groundwater near the well. Following technology installation, the pH increased to a range from 6.2 to 7.9 (see Appendix C). Figures 5-1 and 5-2 show that some metals decreased in concentration (cadmium, copper, zinc, sulfate, and aluminum) while others increased (iron and manganese).

The decrease in the dissolved concentration of certain metals with the corresponding increase in others occurred for several reasons: 1) the changing groundwater level and 2) reducing conditions in the waste pile. From MW2 monitoring well completion diagrams, a decrease in the static water level of 2.4 feet placed the groundwater near the native soil/surface waste pile interface. This means that the lowered groundwater table had less contact with the bulk of the waste pile material, resulting in lower concentrations of most metals. However, the soil/waste pile interface zone contained a greater quantity of ferric iron precipitate than the rest of the pile (Ref. 1). Therefore, the groundwater continued to flow through this concentrated iron precipitate that had settled along the interface.

The spray application of the cover over the waste pile decreased the level of water and oxygen transported into the pile, allowing reducing conditions to be established. This was evidenced by a drop in the E_H values in MW2 (see Appendix C). Under reducing conditions and corresponding increased pH, metals such as copper, zinc, aluminum, and cadmium were precipitated. Other metals such as iron and manganese have increased solubility under these conditions, which explains their increased concentration in MW2.

5.1.4 Monitoring Well 3

Monitoring well 3 (MW3) was located on the west side of WR2 approximately halfway down the length of the pile (see Figure 2-2). Data collection from MW3 began in September 1998 and concluded in September 1999 when the French drain system was constructed. Prior to construction, the pH at MW3 ranged from 6.0 to 6.8, and the metal concentrations fluctuated over time due to seasonal changes.

Static water level data collected from MW3 show a reduction in the static water level because the well became dry after the French drain system was constructed. Groundwater flow followed the hydraulic flow path created by the French drain system, which directed the flow away from the surface waste pile and MW3.

5.1.5 Monitoring Well 4

Monitoring well 4 (MW4) was located near the center of WR2. Data collection from MW4 began in July 1998 and concluded in July 2000. While drilling MW4, drilling was impeded and the monitoring well was unable to penetrate the water table. As a result, monthly data recorded for MW4 illustrated that the well was dry for the duration of the project.

5.1.6 Monitoring Well 6

Monitoring well 6 (MW6) was located on the east side of WR2 approximately halfway down the length of the pile (see Figure 2-2). Data collection from MW6 began in September 1998 and concluded in July 2000. The pH of the groundwater at MW6 ranged from 5.5 to 6.6. After application of the MWTP technologies, MW6 did not recharge fast enough to allow for representative samples to be collected; therefore, MW6 was not used to evaluate the effectiveness of the MWTP technology emplacement.

Static water level data collected from MW6 showed a reduction in the elevation of the static water level under the surface waste pile. Groundwater originally flowed under the surface waste pile. After the French drain was constructed, the flow was hydraulically directed away from WR2 and through the French drain system.

5.1.7 Flumes 1 and 2

The purpose of installing flumes 1 and 2 (F1 and F2) was to measure the amount and quality of the water captured in the French drain system (see Appendix B). Flume 1 (F1) was located on the west side of WR2 and collected the water draining from the westside French drain. Flume 2 (F2) collected the water from the eastside French drain (see Figure 2-2).

Flumes 1 and 2 were in place from November 1999 until August 2000. Water did not flow in F1 until May 2000 because the water was frozen due to winter conditions at the site. Water flow in F1 occurred in May and June 2000 and then became dry again in July 2000. Flume 2 received water flow from May 2000 until the flume was removed. Results from F1 and F2 are shown in Table 5-1. Spring runoff events are clearly depicted and from the results, it is apparent that surface water flow is the main recharge source for F1 and surface and groundwater are the recharge source for F2.

Table 5-1. Water Flow and pH Results for F1 and F2

Parameter	May 2000		June 2000		July 2000		August 2000	
	F1	F2	F1	F2	F1	F2	F1	F2
pH	6.4	7.1	8.1	7.7	NR	7.2	NR	NR
Weir Level (feet)	0.45	0.14	0.19	0.11	NR	0.10	NR	0.10
Weir Flow (gpm)	84.6	4.4	9.6	2.3	NR	1.8	NR	1.8
*NR = No Reading.								

Metal concentrations at both F1 and F2 remained constant during the monitored period (see Appendix C).

5.2 Surface Water Results

The surface water results include data collected at weirs 1, 2, 3, 5, 6, and 7; flume 3 (F3); reflectometers 1 and 2 (RF1 and RF2); and a rain gauge station (see Figures 2-2 and 4-1 and Appendix B). Results for weirs 3 and 4 (W3 and W4) are also included in the report. When the French drain was constructed, W3 and W4 (located on the up-hill side of WR2) were removed because they were in the construction area. Weirs were located around the surface pile and intersected all of the surface water inflow and outflow locations on the Peerless Mine property (see Figure 2-2). Flume 3 was located downstream of the surface pile and was used to monitor the quantity and quality of the runoff water captured in the collection channel.

Using precipitation data from the rain gauge station, peak soil moisture periods were determined and used to evaluate the effectiveness of the jute and 4994 KOBAthane grout cover. Reflectometer 1 was placed in WR1 and was used to collect background percent moisture measurements and data. Reflectometer 2 was placed in WR2.

5.2.1 Weir 1

Weir 1 (W1) was located south of the upper surface pile, WR1, and just downstream of the Peerless Mine adit (see Figure 2-2). Data collection from W1 started in April 1998 and concluded in August 2000. Almost all of the water flowing through W1 was from the lowermost Peerless Mine underground workings. The water quality and flow measurements taken at W1 were designated as background measurements and used as control measurements for this demonstration (Ref. 3). Weir 1 was located upgradient of WR1 and WR2 and as a result, emplacement of the French drain system and the 4994 KOBAthane grout cover did not affect the water quality and flow at W1. The pH at W1 varied from a low of 5.2 to a high of 7.6, and the dissolved metal concentrations and flow through W1 fluctuated due to seasonal changes but on average did not change for the duration of the project (see Figures 5-4, 5-5, and 5-6).

5.2.2 Weir 2

Weir 2 (W2), located on the west side of WR1, was used to measure surface water inflow from the drainage above the lowermost adit (see Figure 2-2). Both water levels and water quality were measured at W2. Data collection from W2 started in April 1998 and concluded in July 2000. Because W2 was located upstream of the surface waste piles, placement of the French drain system and the 4994 KOBAthane grout cover did not have an affect on the water quality. The pH at W2 varied from a low of 5.5 to a high of 7.3

(see Appendix C). Water flow fluctuated with seasonal changes. During spring runoff events, surface water from the drainage above the Peerless Mine adit provided the main source of the water measured at W2. The dissolved metal concentrations on average did not change at W2.

5.2.3 Weir 3

Weir 3 (W3) was located at the west side of WR2 (see Figure 2-2). Data collection from W3 started in April 1998 and concluded in August 1999 when the French drain system was constructed. While W3 was functioning, the pH varied from a low of 5.8 to a high of 7.1. Water flow measurements and dissolved metal concentrations recorded at W3 fluctuated with seasonal changes and on average did not change (see Appendix C).

5.2.4 Weir 4

Weir 4 (W4) was located at the east side of WR2 (see Figure 2-2). Data collection from W4 started in April 1998 and concluded in August 1999 when the French drain was constructed. While W4 was functioning, the pH varied from a low of 5.9 to a high of 7.6. Water flow measurements and dissolved metal concentrations recorded at W3 fluctuated with seasonal changes and on average did not change (see Appendix C).

5.2.5 Weir 5

Weir 5 (W5) was located at the west-side toe of WR2. Data collection from W5 started in April 1998 and concluded in July 2000. The pH at W5 varied from 5.8 to 7.8; however, pH did not change as a result of the MWTP technologies emplacement. Water quality measurements reflected a change in the concentration of certain dissolved metals; the dissolved metals concentrations decreased for iron, manganese, and copper. Other measured dissolved metal concentrations did not indicate any changes. Water quantities were reduced after the installation of the French drain; however, flows recorded at W5 still fluctuated with seasonal changes (see Appendix C).

5.2.6 Weir 6

Weir 6 (W6) was located at the toe of WR2 and monitored the seep flowing from under the toe (see Figure 2-2 and Appendix B). Data collection from W6 began in April 1998 and concluded in August 2000. Weir 6 was designated as a critical monitoring location, and the pH and water quality were the critical parameters measured at W6 (Ref. 3). The data collected at W6 was compared to the water quality at all monitored locations, before and after application of the technologies.

After comparing the measurements taken at W6 over the full duration of the project, visible differences are apparent between the before and after monitoring results (see Figures 5-4, 5-5, and 5-6). The pH at W6 varied from 3.7 to 4.5 before installation of the French drain system and grout cover and from 5.2 to 8.1 after installation (see Figure 5-4). After construction of the grout cover and French drain, the pH increased immediately from an average of 4.0 to 6.3.

Recorded water flow at W6 fluctuated with seasonal changes, but a reduction of water flow was noticed after the MWTP technologies were applied (see Figure 5-7). All of the dissolved metal concentrations were also reduced except for arsenic and silver, which were at laboratory detection limits (see Figures 5-8 and 5-9). After 7 months, the dissolved concentration of iron increased to a level equal to the original concentrations, and the dissolved concentrations of copper, lead, and aluminum also increased but did not reach the original concentrations prior to construction of the MWTP technologies. Since groundwater is the recharge source for the seep at W6, the decrease of the groundwater table by approximately 2.4 feet would directly affect the water quality at W6. It was determined from the well log completion diagrams of MW2, that groundwater is flowing along the native soil and waste material interface. This means that the lower static water levels under WR2 allowed reduced contact time with the bulk of the waste material, resulting in lower concentrations of most metals. However, the soil/waste pile interface zone contained a greater quantity of ferric iron precipitate than the rest of the pile (Ref. 1). Therefore, groundwater continued to flow through the concentrated iron precipitate interface zone.

From the data, it was shown that the implemented spray-applied cover decreased the level of oxygen/water transported through the pile, allowing reduced conditions to establish within WR2. This is evident by a drop in E_H values in MW2 and at W6. Under reducing conditions and corresponding increased pH, metals such as copper, zinc, aluminum, and cadmium remain insoluble or precipitate. Other metals such as iron and manganese increase in solubility under these conditions, causing increased concentrations at W6.

5.2.7 Weir 7

Weir 7 (W7) was located at the eastside toe of the lower surface pile (see Figure 2-2). Data collection for W7 started in April 1998 and concluded in August 2000. The emplacement of the MWTP technologies at WR2 affected the water quality at W7. Before the MWTP technologies were constructed, the pH at W7 varied from a low of 6.0 to a high of 6.6. After the MWTP technologies were placed, the pH at W7 varied from a low of 6.6 to a high of 8.1 (see Figure 5-10). Water quantities were reduced after the installation of the French drain; however, flows recorded at W7 fluctuated with seasonal changes. Visual observations indicate that most of the water flowing through W7 after the MWTP technology installation originated from a spring surfacing approximately 15 feet on the east side of WR2.

Water quality results showed that the dissolved metals concentrations at W7 fluctuated with seasonal changes in surface water flow quantities.

5.2.8 Flume 3

The purpose of flume 3 (F3) was to measure the runoff water captured in the collection channel. Flume 3 was located on the east side and at the toe of WR2 and collected the water draining from the grout cap. Flume 3 was operational in November 1999 and was removed in August 2000. During this period, only a minimal amount of flow was captured in F3 and that was during spring runoff. During the spring runoff period, flows at F3 were difficult to measure because the water would freeze in the trough of the flume during the cold nights and the resulting ice did not fully melt during the day, providing inaccurate flow measurements. The summer of 2000 was dry, and after May 2000, no water was recorded in F3.

5.2.9 Reflectometers FR1 and FR2

Two reflectometers were installed in the two surface waste piles, WR1 and WR2, at the Peerless Mine (see Appendix B). One reflectometer was placed in each surface waste pile and used to determine the percent moisture. Using precipitation data from the rain gauge station, continuous, peak soil moisture data were logged and used to evaluate the effectiveness of the 4994 KOBAthane grout cover. Reflectometer 1 was placed in WR1 and was used to collect background percent moisture measurements and data. Reflectometer 2 was placed in WR2 and was used to determine the percent moisture in the surface waste pile that had been covered with 4994 KOBAthane grout and jute. The reflectometers were installed in the surface waste piles in November 1999, and the continuous output readings remained constant through the winter until March 2000 (see Figure 5-11). From Figure 5-11, it is illustrated that the soil moisture at RF1 (the background reflectometer) is approximately two to three times as much as that at FR2, reducing the soil moisture within WR2 by 60% when compared to the soil moisture in WR1 (the background pile). This reflects that the 4994 KOBAthane cover had an effect on the amount of moisture that infiltrated into the surface waste pile.

During the winter, the reflectometers were not responsive to fluctuations in moisture because the ground was frozen at a depth of 1 foot. However, it was observed that the background reflectometer location began to recognize moisture fluctuations during March 2000 as a result of spring thaw, whereas the covered reflectometer responded to spring thaw at the end of April 2000 (see Figure 5-11).

From the data, it is shown that both instruments recognize rain events and there is a minimal delayed response. Interpretation of the reflectometer data demonstrates that a reflectometer buried 1 foot below the ground surface recognizes a rain event just after it occurs. From this information, the surface waste pile material would be characterized as a porous material having a high infiltration rate. This confirms both the visual observations of the surface waste pile and the sieve analysis performed for the project (Ref. 1).

5.3 Emplacement Observations and Results

During construction of the French drain system and emplacement of the 4994 KOBAthane grout cover, the following observations were made.

1) The surface waste pile, WR2, was very heterogeneous; the waste material contained a mixture of very fine silt mixed with cobbles (6- to 12-inch rock material). Most of the material contained high sulfide rock.

2) The surface waste pile was disturbed during the emplacement of the collection channel and during preparation of WR2 for acceptance of the grout cover. It was difficult to spray apply the 4994 KOBAthane grout cover to the disturbed areas of the pile because the fine, disturbed soil would dislodge and become airborne or roll down the slope. The disturbed material would follow preferential pathways on the steeply sloped areas.

3) In the steeply sloped portions of the pile, the grout followed the preferential pathways, which resulted in sagging. This was due to both the spray tip being too large, allowing too much material on a sprayed area, and the lack of thixothropic properties of the grout product.

4) It was observed that application of the grout directly to the surface waste pile was fairly successful. Many of these spray-applied areas achieved a seal that served to stabilize the surface waste pile; however, voids were visible around larger rocks. Spraying directly onto irregular surfaces increased the amount of material used because of the increased surface area. The application time and cold weather also made it difficult to make the cover impervious.

5) In areas where the 4994 KOBAthane grout material was applied over areas of snow and ice, curdling of the grout occurred, resulting in weaker grout. In some areas, the curdling effect caused the cover to have small holes in the areas where the snow was sprayed. From visual observations, it was determined that approximately 80% of the pile was covered.

6) In was observed that after the grout had cured for a minimum of 24 hours, people were able to walk on the stabilized surface. The binding of the grout to the surface waste pile material resulted in decreased erosion effects during precipitation events.

7) Unlike standard liner materials, spray-applied covers are less equipment intensive (i.e., there is less site preparation so no heavy equipment is necessary, and they can be applied to steep and inaccessible areas).

8) In some areas of the surface waste pile, the 4994 KOBAthane grout was sprayed onto 1/8-inch woven burlap and 3/4-inch woven jute material instead of being sprayed directly onto the surface waste pile. In those areas, less grout was required, and the final stabilized area produced an impermeable, continuous capped layer that bonded to the surface waste pile. Unlike the areas where the grout material was applied directly to the surface waste pile, no holes were present where there was jute and burlap fabric.

9) To construct the French drain system, the water discharging from the Peerless Mine adit was diverted away from the WR1 and WR2. Originally, the average flow from the seep at the toe of WR2 was approximately 4 gpm. After the French drain was installed, the water flow at the toe of WR2 was reduced approximately 2 gpm. However, once the water from the adit was placed back into its original flow regime, the flow at the toe of the surface waste pile increased to approximately 3 gpm, and flow measured 0.5 gpm at the flumes connected to the French drain system, showing that the system had recharged.

10) The pH at W6 before the demonstration averaged approximately 3.8. However, a month after the demonstration project was completed, the pH reading was 5.78, and 2 months after the demonstration project, the pH reading was 7.28. Long-term monitoring results are provided in Appendix C and on Figure 5-4.

5.4 Overall Results

To determine if the objectives of the QAPP were accomplished and if the technologies were effective in achieving the primary project objectives, several different types of monitoring methods were used at the Peerless Mine. The primary objective was to construct an impervious barrier system that would reduce and/or eliminate the influx of groundwater and surface water through the surface waste pile. To achieve this goal, the French drain system was constructed as a hydraulic barrier to eliminate and reduce groundwater flow through the surface waste pile, and the 4994 KOBAthane grout cover was emplaced to reduce the amount of precipitation infiltrating into the surface waste pile.

In order to monitor the effectiveness of the 4994 KOBAthane grout cap and French drain system, the groundwater, surface water, and soil moisture were monitored for 3 years. The critical measuring location was determined to be W6, where the water discharged from the toe of WR2. From monitoring W6 on a long-term basis, it was shown that the water flowing through W6 was reduced by approximately 1 gpm, due to the placement of the MWTP technologies (see Figure 5-10). Also, at W6, the pH of the water increased from a 3 to 4 range to a 5 to 8 range after construction was complete (see Figure 5-10). The dissolved metal concentrations for copper, zinc, cadmium, and aluminum declined, proving the grout cover and French drain system had a positive impact on the water discharging into the Banner Creek drainage.

Also, at MW2 and W6, the E_H measurements were lower by an order of magnitude, and the concentration of dissolved iron and manganese increased after the technologies had been applied for several months. These changes were attributed to the surface waste pile being changed from an oxidized to a reduced environment, resulting from the application of the grout cover. Indications of the reduced environment within the surface waste pile after the technologies were applied include lower E_H measurements, higher pH values, reduced conductivity, and reduced temperature measurements. The ferric iron precipitate converted to ferrous iron in solution causing an increase in the dissolved metals concentrations.

Other monitoring locations that reflected the effectiveness of the implemented MWTP technologies include the surface water monitoring at W7; the flow decreased and the pH increased immediately after the technologies were placed. The static water level at MW2 located in WR2 decreased by 2.4 feet, and the dissolved metals concentration of cadmium, copper, sulfate, nickel, zinc, and aluminum in the groundwater also decreased. After construction of the French drain system, MW6 and MW3 contained water only during the high runoff season.

From the results acquired by the continuously monitored reflectometers, it was determined that the background reflectometer, RF1, measured approximately two to three time the amount of soil moisture in WR1 when compared to RF2 in WR2, the covered surface waste pile. This indicated that less moisture was penetrating WR2 than WR1 and that the 4994 KOBAthane grout cover was effective in reducing the amount of moisture infiltrating the surface waste pile. However, from the visual observations, it was determined that the cover was approximately 80% impermeable. From the reflectometer data, it was determined that the percent moisture in the pile had been reduced to 60% as a result of the cover installation.

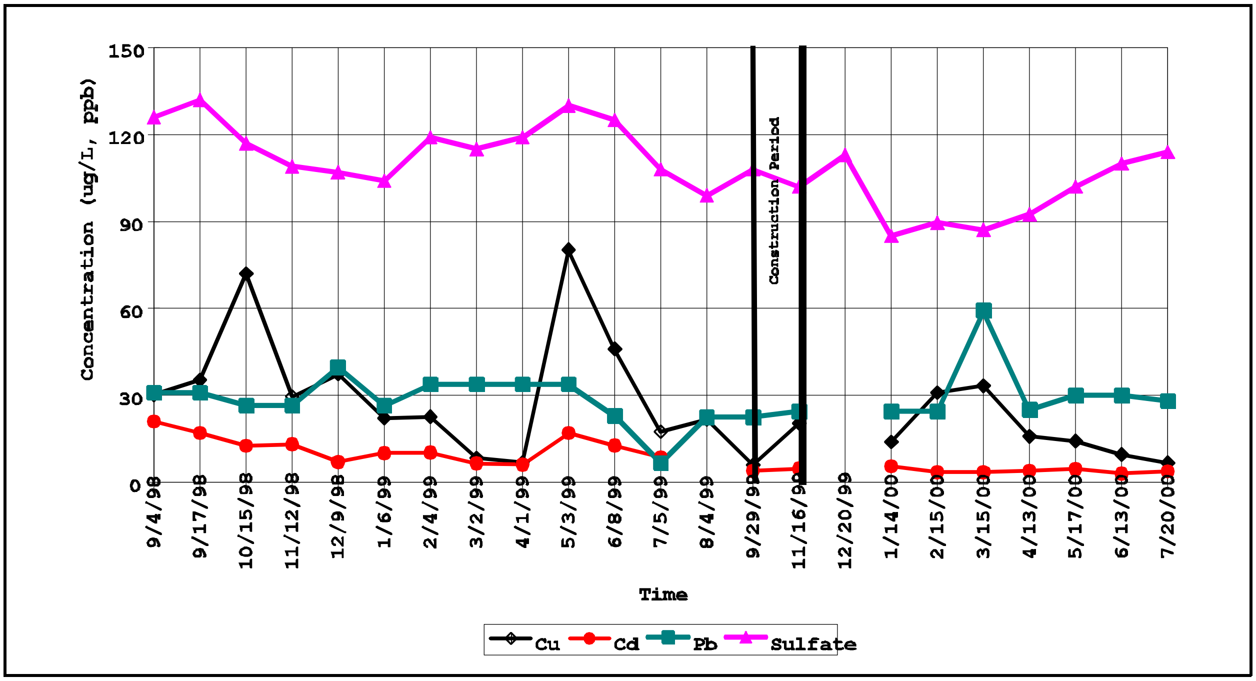

Figure 5-1. Peerless Mine—Monitoring Well 2 metal and sulfate concentrations versus time.

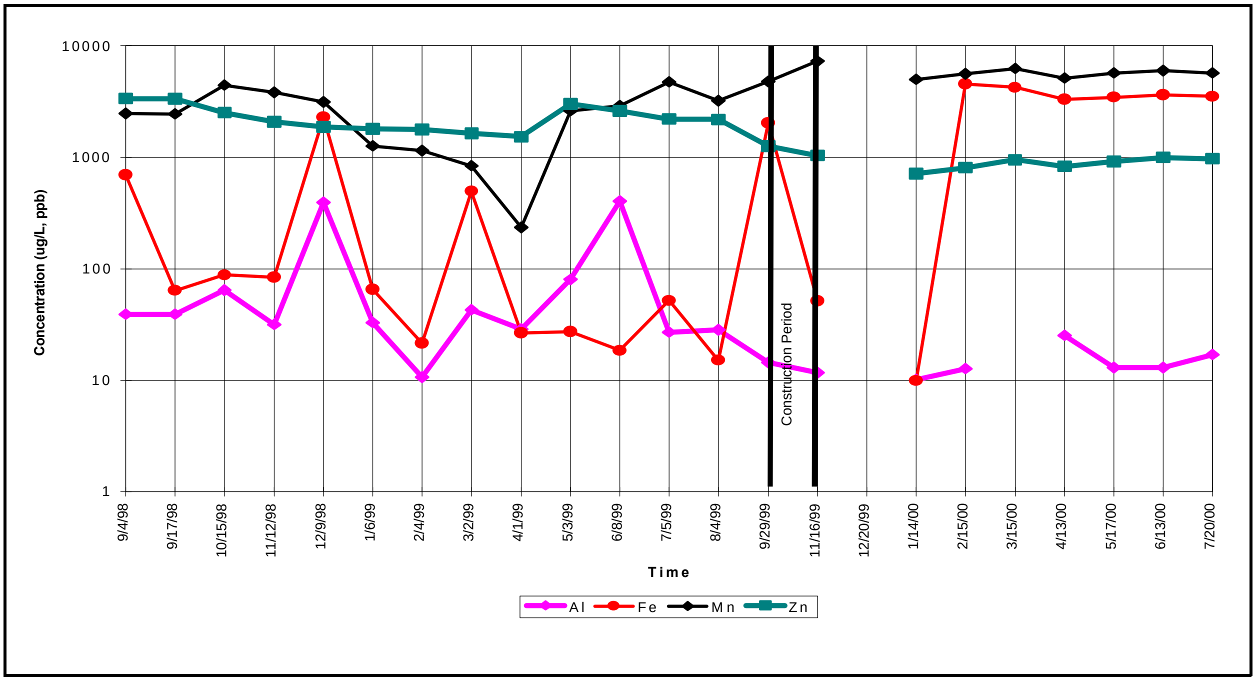

Figure 5-2. Peerless Mine—Monitoring Well 2 metal concentrations versus time.

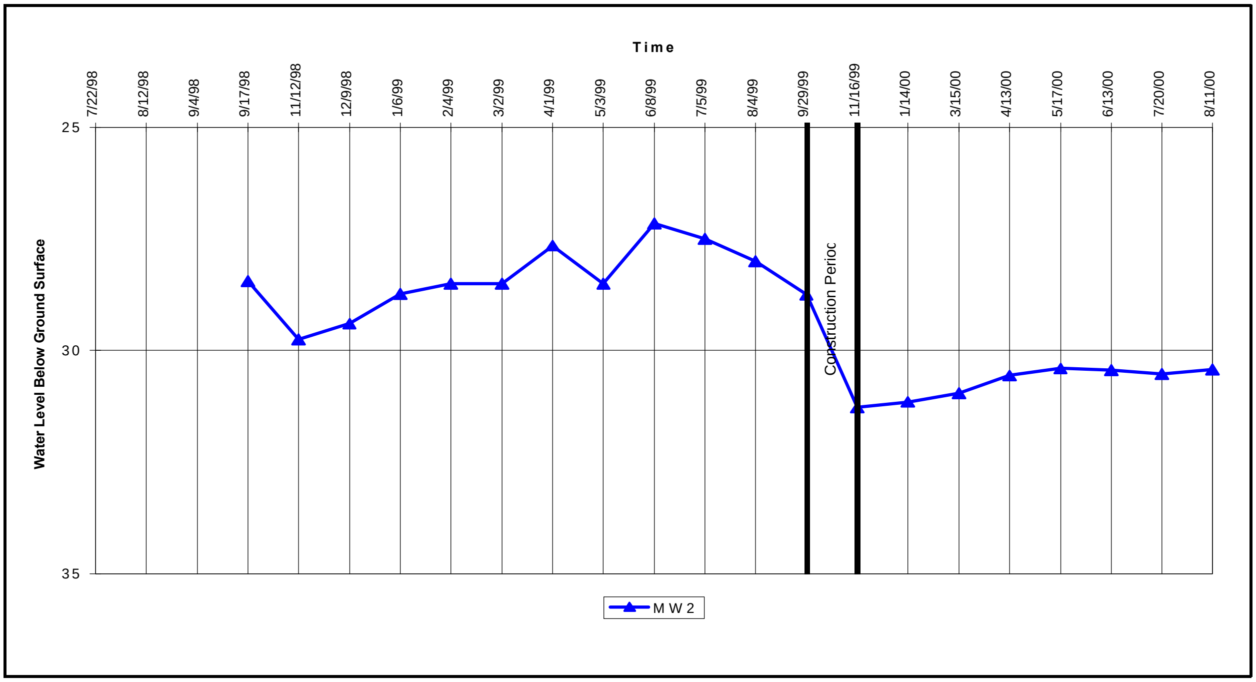

Figure 5-3. Peerless Mine—Monitoring Well 2 static water level.

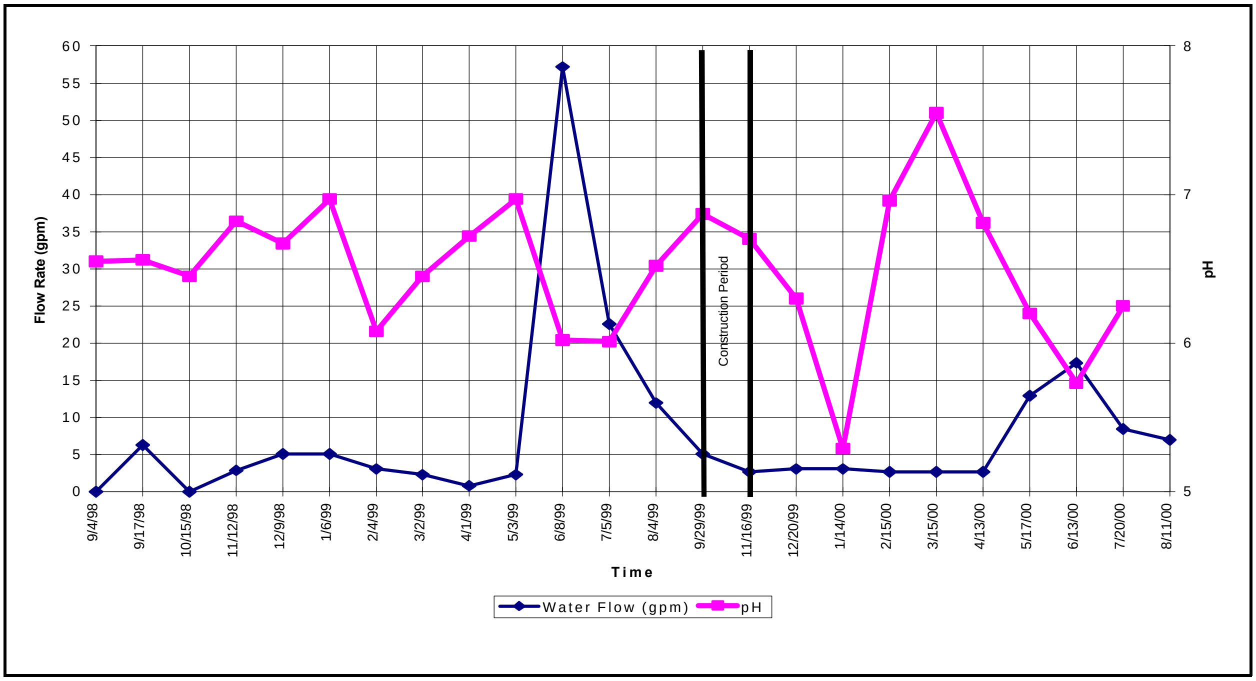

Figure 5-4. Peerless Mine—Weir 1 water flow and pH versus time.

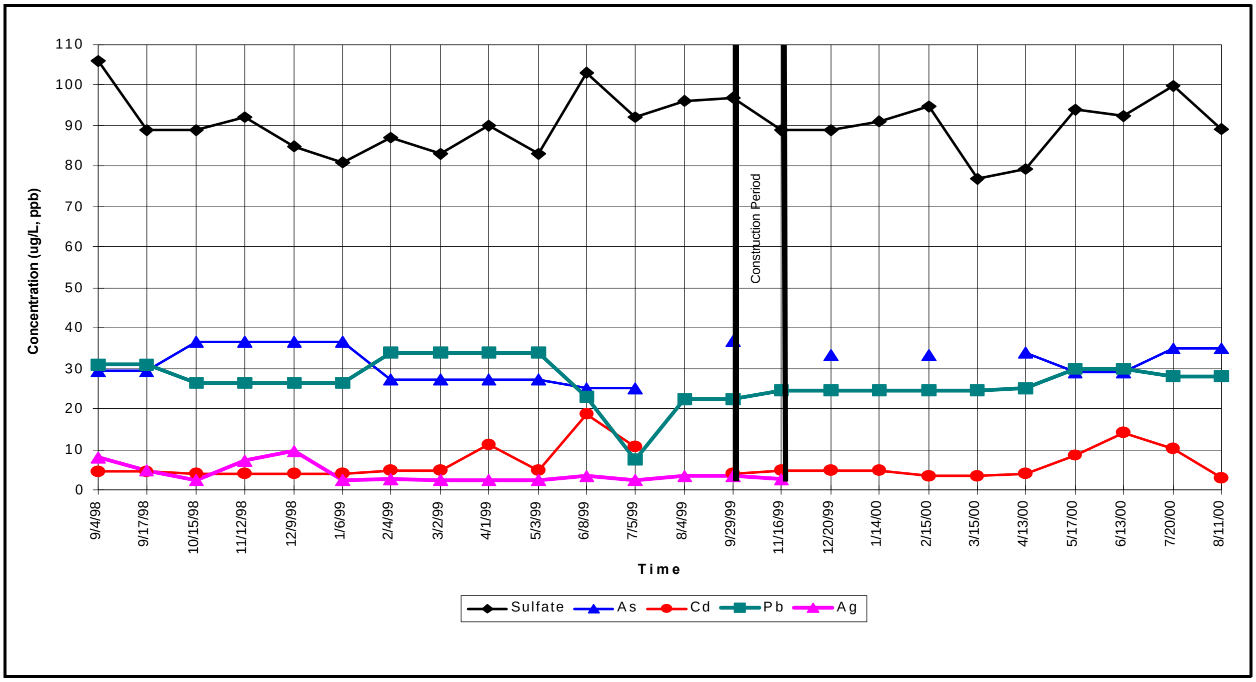

Figure 5-5. Peerless Mine—Weir 1 metal concentrations and sulfate versus time.

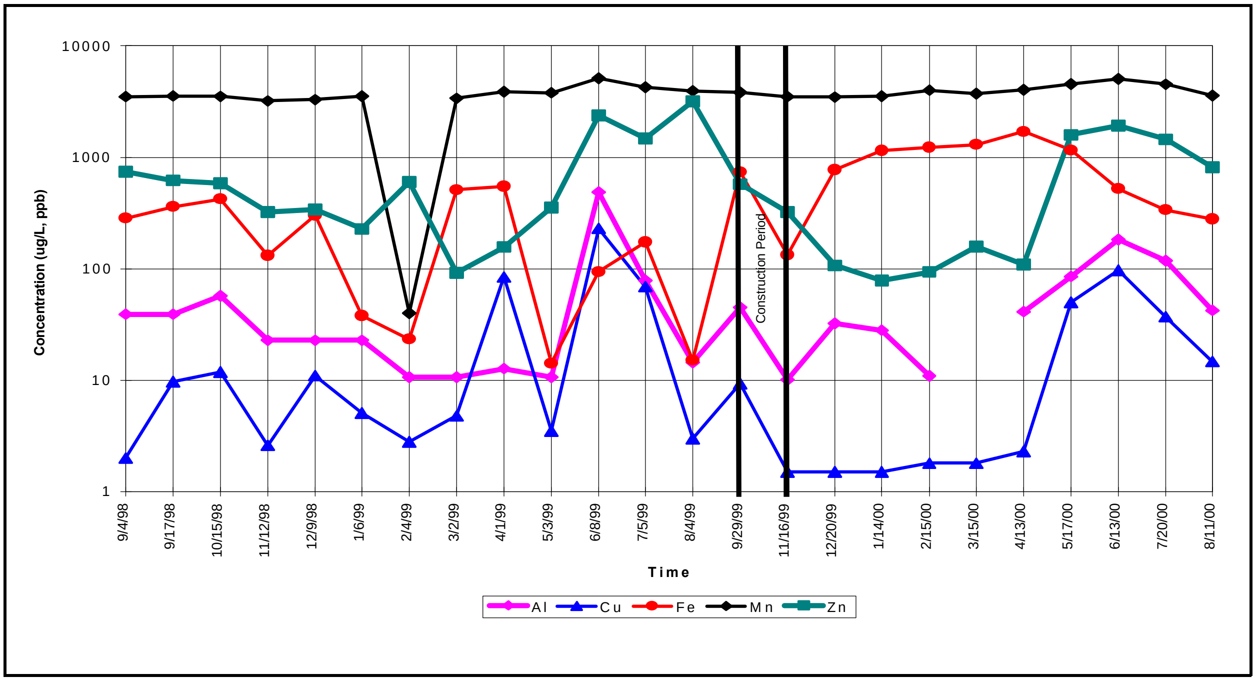

Figure 5-6. Peerless Mine—Weir 1 metal concentrations versus time.

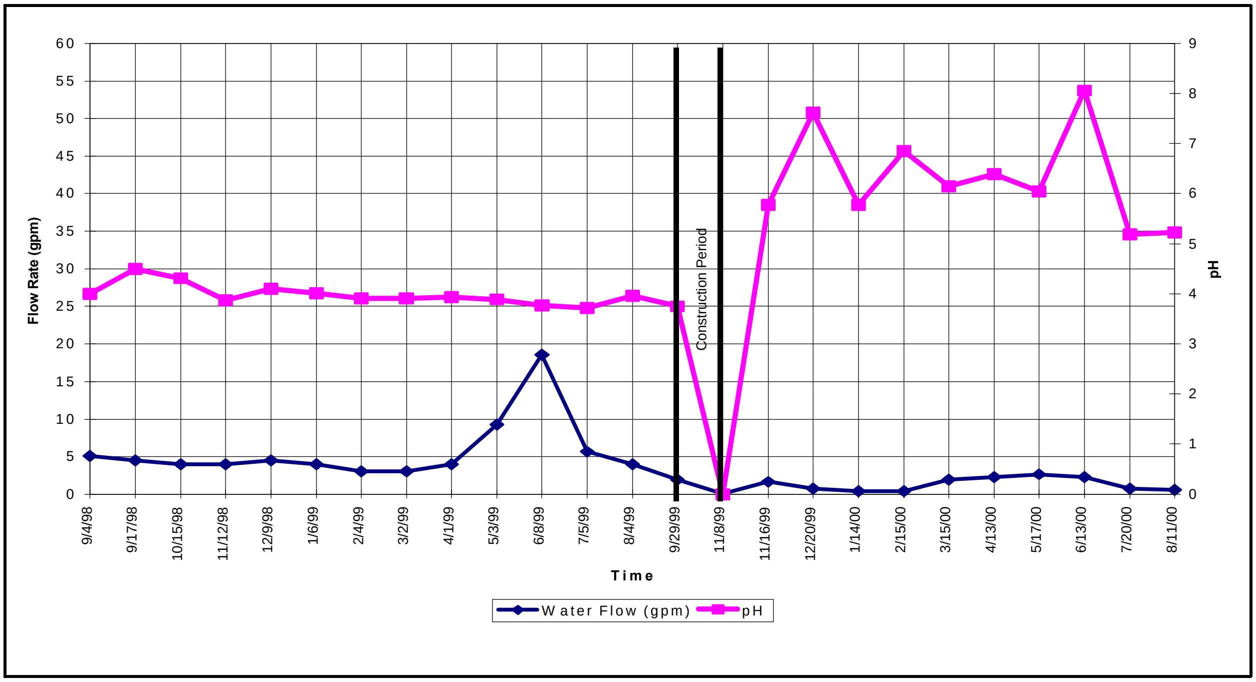

Figure 5-7. Peerless Mine—Weir 6 water flow and pH versus time.

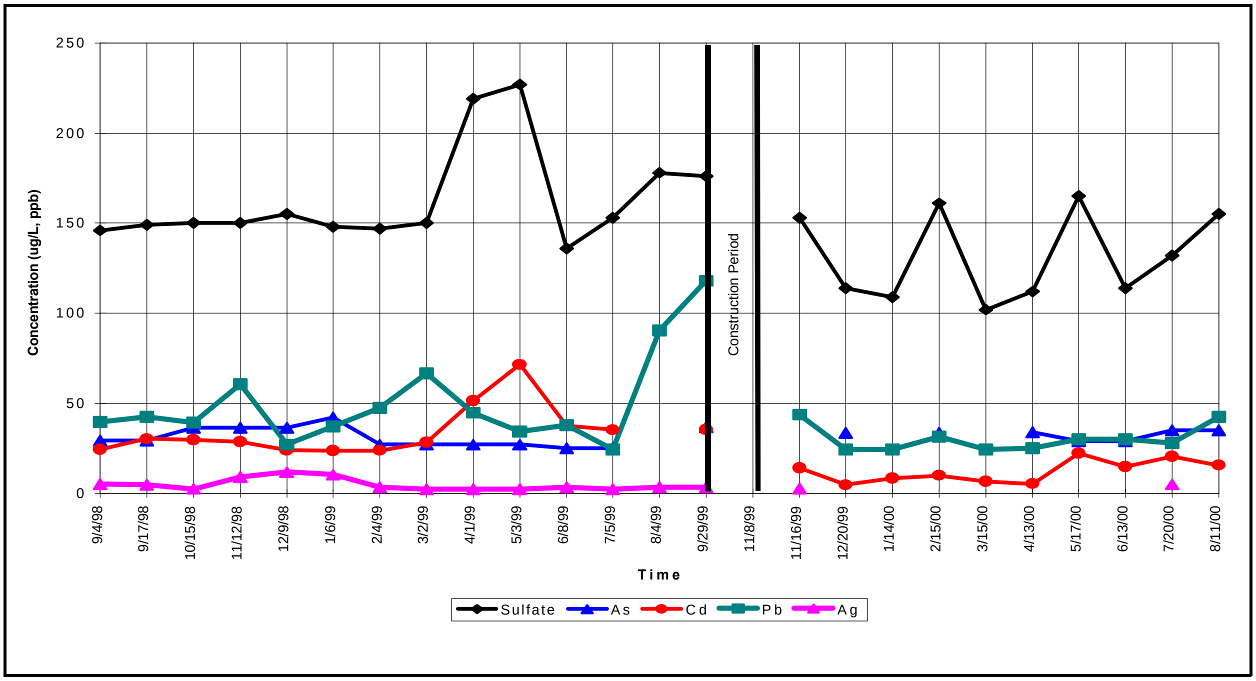

Figure 5-8. Peerless Mine—Weir 6 metal concentrations and sulfate versus time.

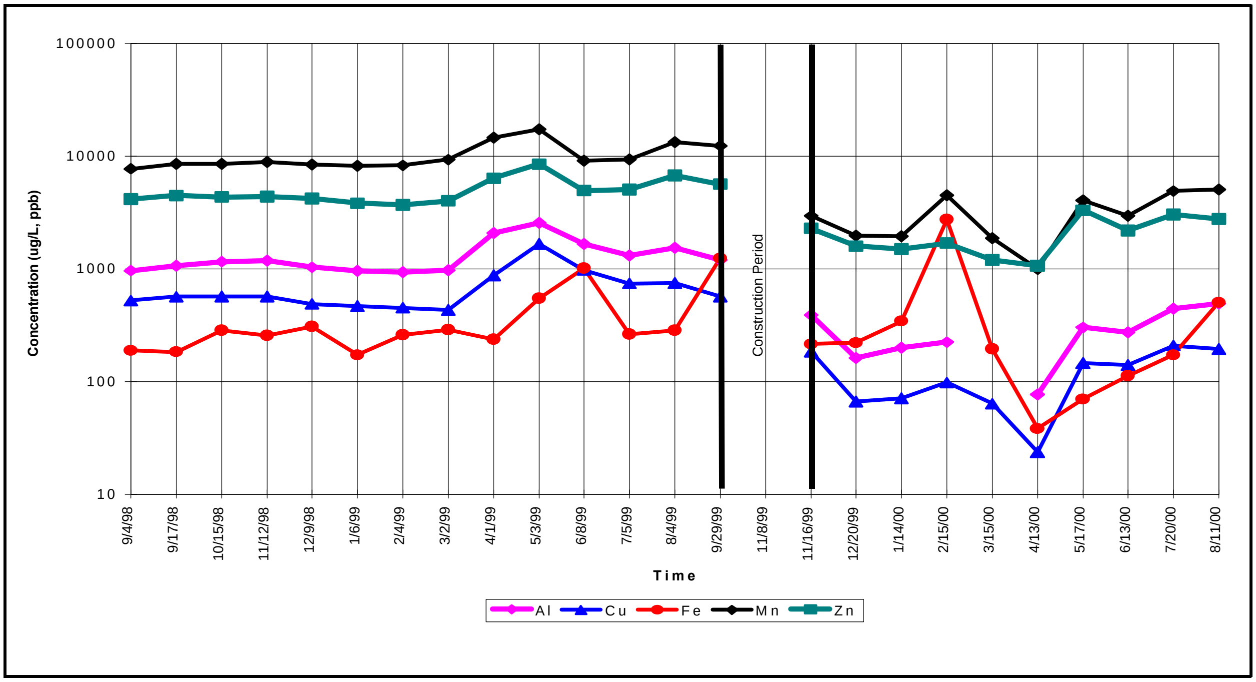

Figure 5-9. Peerless Mine—Weir 6 metal concentrations versus time.

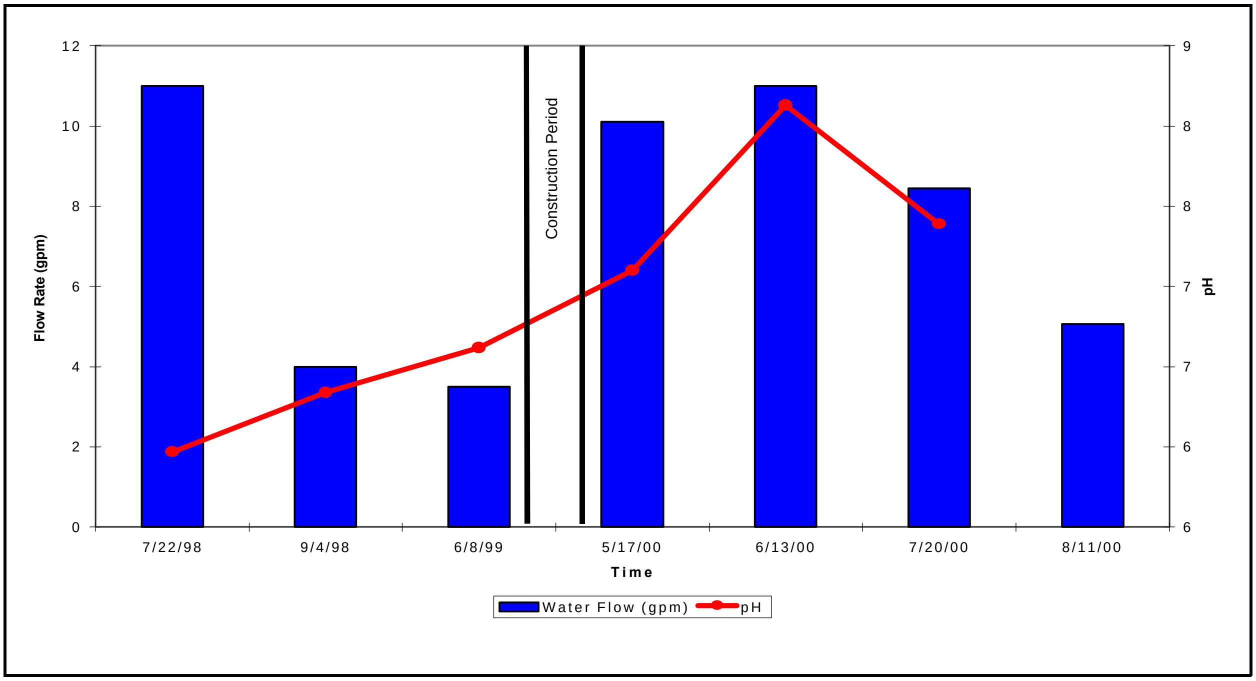

Figure 5-10. Peerless Mine—Weir 7 water flow and pH (pre- and post-construction) versus time.

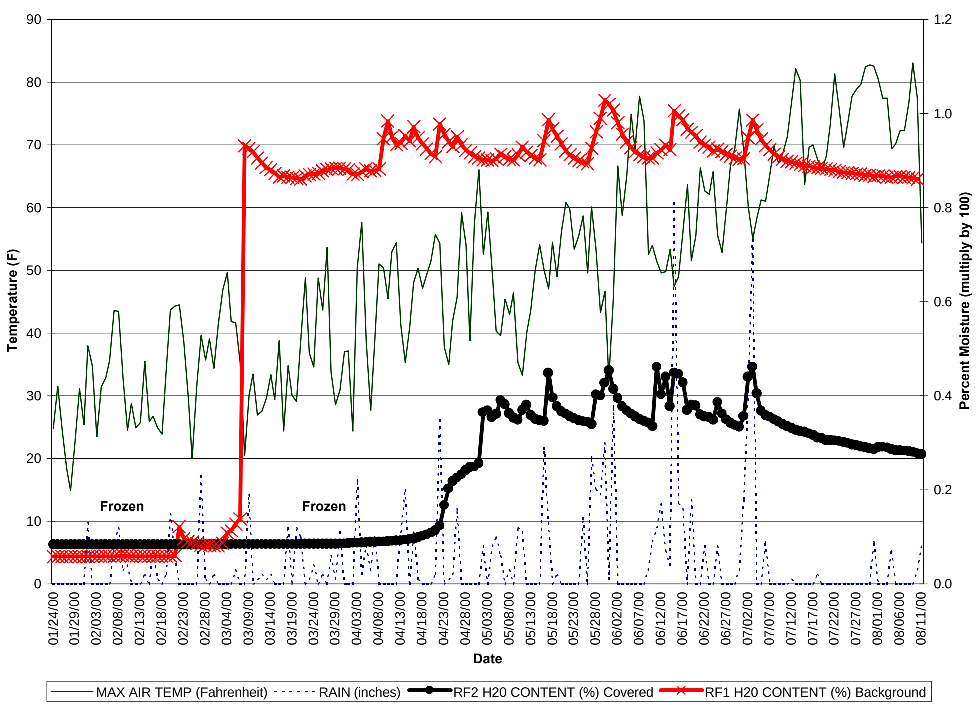

Figure 5-11. Reflectometer precipitation penetration into WR1 and WR2 versus time.

6. Conclusions and Recommendations

The objective of the technology demonstration was to determine the effectiveness and feasibility of using a source control technology to provide in situ stabilization/encapsulation to reduce and/or eliminate infiltration of surface water and shallow groundwater into the surface waste pile.

To reduce the amount of groundwater flowing through the surface waste pile, a French drain system was installed to act as a hydraulic barrier, which provided a preferential pathway directing groundwater flow away from the surface waste pile. Installation of the French drain system resulted in reduced static water levels under the surface waste pile and a decrease in the dissolved metals concentrations in the groundwater. However, to reduce these parameters further, emplacement of a biobarrier on the downgradient side of the French drain would further treat or divert the water away from entering the groundwater system under the surface waste pile.

Overall, the field emplacement of the French drain system and the 4994 KOBAthane grout cover decreased the dissolved metal concentrations in the water discharging from the surface waste piles at the Peerless Mine to levels below the National Drinking Water Maximum Contaminant Standards. The main metals reduced were zinc, cadmium, and copper. If these MWTP technologies were installed at another surface waste pile, the spray-applied grout cover should be applied to a surface waste pile that is covered with either a geotextile or jute fabric and then spraying the fabric with a flexible, modified polyurea grout material. If there were groundwater contamination problems at the site, installing the French drain system with the biobarrier on the downgradient side of the French drain would be a viable option. Applying the option described above would decrease the groundwater contamination while providing in situ stabilization of the surface waste pile.

From the results, it is apparent that the 4994 KOBAthane grout cap and French drain installation improved the water quality at the toe of the surface waste pile. This statement was substantiated by the rise in pH levels at W6 from 3.8 to 7.3; the decrease in water temperature of approximately 2 degrees; and the decrease in dissolved metal concentrations for copper, zinc, and cadmium at the toe of the surface waste pile.

From observations made during the spray application of the 4994 KOBAthane grout cover; it was determined that the cover reduced infiltration of water through the surface waste pile. However, the 4994 KOBAthane grout material was adversely affected by the cold and wet weather conditions. Further material testing will be performed at the Mammoth tailings site. During this testing, the grout material will be modified and will have the ability to set up in less than 5 minutes, will have the ability to be flexible, and will not be affected by the cold and wet conditions at the site.

Spraying the grout material directly onto the surface of the waste material increased the amount of grout material used because it is difficult to cover large rock material. It was concluded that if a jute and burlap material was applied to the surface waste pile prior to spraying the grout cover, less grout material would be required to cover the rock material and the grout cover would be impervious. Because the grout binds into the woven fibers of the jute and burlap material, less grout was required to achieve the desired coverage over the pile, and the spray-applied grout would not flow down the slope following preferential pathways. It formed a smooth, expandable, and consistent grouted surface.

In areas where the slope was steep, the grout product should have been made more thixotropic, allowing the grout to adhere to the soil on the sloped area in which spraying was performed rather than flowing down the slope. Using a material with a short set time would also reduce the amount of material that flows down the slopes.

For future applications, the spray equipment and tips should be optimized to determine which applicators will provide the best cover and provide ease of application. By optimizing the equipment, this grout material could be applied at locations that have steep slopes and are inaccessible to large earth-moving equipment.

If work were to be performed at a similar surface waste pile, the collection channel and LLDPE liner could be eliminated by using spray-applied grout for the collection channel. Using a spray-applied grout material instead of the LLDPE liner would prevent disturbance of the surface waste pile by eliminating the trenching needed for tucking the liner into the pile. It would also create a smoother drainage transition for the runoff water flowing off the surface of the pile into the collection channel.

Extended monitoring revealed that the grout worked as a cover material to reduce or prevent infiltration through the surface waste pile and was effective at reducing and eliminating erosion of waste material into adjacent receiving surface waters. In these instances, the cover does not need to be 100% impervious but can be sprayed thinner and allow for water to infiltrate. However, it would still reduce the erosion of loose sediment or waste material from entering the associated receiving streams.

7. References

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Appendix A

Summary of Quality Assurance Activities
Mine Waste Technology Program
Activity III, Project 10
Surface Waste Piles Source Control Demonstration (Peerless Mine)

1. BACKGROUND

On November 12, 1998, sampling officially began for Mine Waste Technology Program (MWTP) Activity III, Project 10, *Surface Waste Piles Source Control Demonstration Project*. This demonstration was conducted at the Peerless Mine site near Helena, Montana. The intent of the project was to reduce or eliminate the influx of water through and into a surface waste pile located at the site by using innovative source control techniques. The project was divided into three phases:

- Phase I–Mine Site Selection/Site Characterization
- Phase II–Source Control Materials Testing
- Phase III–Field Emplacement of the Selected Source Control Technologies

All work during Phase I and Phase III was performed under an approved quality assurance project plan (QAPP). Work during Phase II was performed under a test plan but did not have any direct quality assurance (QA) oversight, although guidance was provided by the MSE QA Department when requested.

Phase I had the following specific objectives:

- characterize the surface waste pile at the Peerless Mine to provide baseline information with respect to hydraulics and physical characteristics and determine where the inflows and outflows from the surface waste pile occur along with the structures controlling the inflows and outflows; and
- determine the quality and quantity of each source contributing to the flow in or out of the surface waste pile at the Peerless Mine by analyzing dissolved metals concentrations and pH of each flow.

The information gathered during Phase I was used during Phase III to assess the performance of the source control technologies chosen during Phase II. Phase III had the specific objective of preventing groundwater, surface water, and precipitation from contacting the selected surface waste pile, designated WR2, and negatively impacting water quality discharging from the pile at weir location 6 (W6) with respect to pH and dissolved metals concentrations.

Samples were collected according to the schedule outlined in the approved project-specific QAPP document. Phase I and Phase II work were performed concurrently. The Phase I QAPP was endorsed by the U.S. Environmental Protection Agency's (EPA) National Risk Management Research Laboratory (NRMRL) on August 4, 1998. The QAPP was then edited to include the Phase III work and was endorsed by NRMRL on November 9, 1999. All field and laboratory data available from

Phases I and III have been evaluated to determine the usability of data. Surface water flow rate (manual and weir); pH; and dissolved metals analyses [aluminum (Al), arsenic (As), silver (Ag), cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), and zinc (Zn)] were classified as critical parameters for this project. A critical analysis is an analysis that must be performed in order to determine if project objectives were achieved. Data from noncritical analyses were also evaluated.

2. PROJECT REVIEWS

During the project, a preproject evaluation of the HKM Laboratory and a field documentation review were performed.

2.1 Preproject Evaluation of HKM Laboratory

Before the project began, a determination was made as to whether the HKM Laboratory was prepared/ qualified to perform dissolved metals analysis for this project. HKM holds accreditation from the following organizations that perform routine external audits:

- certified by the Montana Department of Health and Environmental Sciences for public water supply and National Pollution Discharge Elimination System (NPDES) analyses;
- certified by the Montana Air Quality Bureau for air filter analyses;
- certified by EPA Region VIII for performing hazardous waste Resource Conservation and Recovery Act (RCRA) analyses; and
- certified by the U.S. Department of Energy's (DOE) Environmental Restoration Program-approved laboratory.

In addition to the external audits, HKM Laboratory 's QA Officer performs annual internal audits. The HKM Laboratory was deemed qualified to perform the analysis for the project.

HKM also receives performance evaluation samples. Applicable performance audits by the EPA through the State of Montana were also reviewed, and the results are summarized in Table 1. Performance audits help ensure comparability to other analytical laboratories.

2.2 Field Documentation Review

A field documentation review was performed on November 12, 1998. The purpose of the field documentation review was to ensure that the measurements being recorded and the samples being collected in the field were consistent with the requirements of the project-specific QAPP. The field documentation review included a review the field project logbook and the chain-of-custody (COC) form from the sampling event of November 12, 1998. All COC procedures were being followed. Sampling personnel were familiar with the logbook format and COC procedures. The following deficiencies were noted with the sampling logbook:

- an area is needed in the logbook to document equipment calibrations; and
- an area is needed in logbook to document pH accuracy. From information gathered, only precision could be determined from the duplicate pH reading. A mid-range pH buffer check is needed to determine the accuracy of the pH measurements.

Table 1. Performance evaluation sample summary (PE005, 5/12/98).

Analyte	Reported Value	True Value	Acceptance Limits	Performance Evaluation
(PE005, 5/12/98)				
Fe	179 mg/L	191 mg/L	165–218 mg/L	Accept
Mg	507 mg/L	530 mg/L	485–587 mg/L	Accept
Sulfate	60.8 mg/L	58.0 mg/L	51.3–65 mg/L	Accept
pH	5.04	5.03	4.93–5.14	Accept
WS-32, 6/3/99				
pH	7.74	7.80	7.02–8.58	Accept
Mercury (Hg)	2.6	3.3	2.31–4.29	Accept
Al	745	750	644–870	Accept
As	34.1	33.3	29.0–37.3	Accept
Cd	34.8	33.3	26.0–40.0	Accept
Cu	81.8	83.3	75.0–91.6	Accept
Fe	393	400	311–486	Accept
Pb	54.9	50.0	35–65	Accept
Manganese (Mn)	450	467	435–491	Accept
Zn	756	800	734–860	Accept

As corrective actions, the requested changes were made to the sampling record forms. A buffer of pH 5.0 was procured to serve as the mid-range buffer check during subsequent sampling events.

3. DATA EVALUATION

The data quality indicator objectives for the critical analyses were outlined in the QAPP and were compatible with project objectives and the methods of determination being used. The data quality indicator objectives are method detection limits (MDLs), accuracy, precision, and completeness. Control limits for each of these objectives are summarized in Table 2.

Table 2. Data quality indicator objectives.

Measurement	Units	Precision[1]	Accuracy	Completeness[2]	MDL
Weir water depth	inches	N/A[3]	0.1%/0 to 1 psi	95%	0.1
Surface water flow rate (weir)	gpm	N/A[3]	±5% (2 to 15 gpm)	95%	2
Surface water flow rate (manual)	mL/min	±20 mL/min[4]	N/A	95%	20
pH	S.U.	±0.2[5]	±0.2[6]	95%	2.0
Dissolved metals	mg/L	#20% RPD	75%-125% spike recovery	95%	
Al					0.05
As					0.05
Cd					0.01
Cu					1.3
Fe					0.3
Pb					0.05
Mn					0.05
Zn					5.0
Ag					0.05
Hg					0.002

1 Precision will be determined by the relative percent difference (RPD) of duplicates, unless otherwise indicated.
2 Completeness is based on the number of valid measurements, compared to the total number of samples.
3 Duplicate measurements of field process measurements will not be taken. All equipment is calibrated against National Institute of Standards and Technology (NIST) traceable standards.
4 Precision of manual surface water flow rate measurements will be determined by the absolute difference between two consecutive measurements of the same sample.
5 Precision of pH measurements will be based on the absolute difference of duplicate readings.
6 Accuracy of pH measurements will be based on absolute difference of reading compared to standard buffer solution

All data quality indicator objectives were achieved with the exception of the surface water flow rate objectives. Duplicate measurements were not taken as described in the QAPP. Stopwatch/graduated cylinder flow checks were not performed. Instead, manual checks were performed by using a staff gauge to measure the head built up behind the weir or the head on the flume freeboard. It became apparent that the pressure transducers installed in the flume and weirs did not give accurate results due to fouling from sediment and other debris. During each sampling event, the weirs were cleared of debris, and the pressure transducers were cleaned. By the end of the project, the manual head readings were used to calculate the flow rates for reporting purposes. To ensure comparability, the manual readings for the entire project were used for reporting purposes.

4. VALIDATION PROCEDURES

Data that were generated to date for all analyses were validated. The purpose of data validation is to determine the usability of data that were generated during a project. Data validation consists of two separate evaluations: an analytical evaluation and a program evaluation.

4.1 Analytical Evaluation

An analytical evaluation is performed to determine the following:

- that all analyses were performed within specified holding times;
- that calibration procedures were followed correctly by field and laboratory personnel;
- that laboratory analytical blanks contain no significant contamination;
- that all necessary independent check standards were prepared and analyzed at the proper frequency and that all remained within control limits;
- that duplicate sample analysis was performed at the proper frequency and that all Relative Percent Differences (RPDs) were within specified control limits;
- that matrix spike sample analysis was performed at the proper frequency and that all spike recoveries (%R) were within specified control limits.

Measurements that fall outside of the control limits specified in the QAPP, or for other reasons are judged to be outlier, were flagged appropriately to indicate that the data is judged to be estimated or unusable.

4.1.1 Field Data

Field data was evaluated to determine the usability of the data. The project-specific QAPP was used as a guide, and several observations were made regarding deficiencies in the field data. As mentioned previously, manual flow measurements were different than described in the QAPP. The other field measurements included pH, oxidation-reduction potential (E_H), temperature, resistivity (moisture content), and precipitation. The field logsheets included a space for recording of all measurements. All measurements were recorded when possible. During much of the project, not all planned measurements could be taken due to freezing conditions or dry wells/weirs. On other occasions, no explanation was provided for why certain measurements were not taken. If data cannot be collected, the reasons should be documented in the logbook.

On December 9, 1998, May 3, 1999, June 8, 1999, and July 5, 1999, the manual staff gauge readings were recorded in the logbook as an order of magnitude higher than actual. While the Project Manager corrected the entries in the logbook and explained how to correctly read the staff gauges, all sampling personnel should be trained how to read the field instrumentation properly.

The samples collected on December 9, 1998, were not received at the HKM laboratory until December 31, 1998. The reason for the delay was that the samplers became busy with another task and forgot about the samples. The samples were stored in a refrigerator in the Resource Recovery Facility. Samples should be delivered to the laboratory as soon as possible after sampling.

4.1.2 Laboratory Data

An analytical evaluation was performed to determine the usability of the data that was generated by the HKM Laboratory for the project (see Section 4.1 for a description of what the analytical evaluation entails). Laboratory data validation was performed using *EPA Contract Laboratory Program National Functional Guidelines for Inorganics Data Review* (EPA, 1994) as a guide. The QC criteria outlined in the QAPP were also used to identify outlier data and to determine the usability of the data for each analysis. None of the laboratory data required flags. Two serial dilution samples (sampling events December 9, 1998 and February 4, 1999) were outside the performance limits of ±10% difference for aluminum analysis; however, sample concentrations were not high enough [50 times the instrument detection limit (IDL)] to be flagged. In addition to the analytical evaluation, a program evaluation was performed.

The only other problem experienced at the laboratory for this project was that the field blank sample from August 4, 1999, was used to prepare QC check samples (duplicate, spike) in the laboratory. Because the matrix of the samples from this project was not troublesome for the laboratory during previous or subsequent analysis activities, the data were not flagged. A corrective action was taken to designate a few samples from subsequent sampling events that the laboratory could choose from to prepare internal QC check samples.

4.2 Program Evaluation

Program evaluations include an examination of data generated during the project to determine the following:

- that all samples, including field QC samples were collected, sent to the appropriate laboratory for analysis and were analyzed and reported by the laboratory for the appropriate analyses;
- that all field blanks contain no significant contamination; and
- that all field duplicate samples demonstrate precision of field as well as laboratory procedures by remaining within control limits established for RPD.

Program data that were inconsistent or incomplete and did not meet the QC objectives outlined in the QAPP were viewed as program outliers and were flagged appropriately to indicate the usability of the data.

4.2.1 Field QC Samples

In addition to internal laboratory checks, field QC samples have been collected to determine overall program performance. The following sections describe out-of-control field blanks and field duplicates.

4.2.2 Field Blanks

Six of the field blanks collected (November 12, 1998, May 5, 1999, June 8, 1999, July 12, 1999, August 8, 1999, and February 15, 2000) for the project showed significant contamination for various dissolved metals. Associated samples with less than 10 times the contamination were flagged "U" for the appropriate analytes. A "U" flag indicates the data are undetected below the associated value. Zinc was the most common contaminant found in the field blanks.

4.2.3 Field Duplicates

Three field duplicates (January 6, 1999, April 2, 1999, and June 8, 1999) collected were outside control limits for various dissolved metals. While EPA does not specify control limits for field duplicates, the data reviewer is allowed discretion when evaluating field duplicates. For this project, precision control limits of #35% RPD (or ± contract required detection limit (CRDL) when samples are less than 5 times the IDL) were used for field duplicates.

Affected analyses included cadmium, copper, manganese, and zinc. Table 3 summarizes all of the data that were flagged for various reasons throughout the project, including field duplicates. All data are considered usable for arriving at project conclusions.

Table 3. Summary of qualified data for MWTP Activity III, Project 10 .

Date[1]	Sample ID	Analysis	QC Criteria	Control Limit	Result	Flag[2]	Comment
11/12/98	PM-MW1 PM-MW2 PM-MW3 PM-MW6 PM-W1 PM-W3 PM-W6	Dissolved Silver	Field Blank	No significant contamination, #2x IDL or 8.2 ppb	10.8 ppb	U	Samples with less than 10 times the contamination concentration in the blank, but above the MDL should be flagged "U".
1/6/99	PM-MW1 PM-MW2 PM-MW3 PM-MW6 PM-W1 PM-W3 PM-W6	Dissolved Cadmium Manganese Zinc	Field Duplicate	±2 x IDL (8ppb) #35% RPD #35% RPD	16.6 ppb 92.7% RPD 94.0% RPD	J	Because samples were #5 times the IDL for cadmium, the normal precision control limit of #35% RPD did not apply. An alternative control limit of ±2 times the IDL was applied and resulted in the cadmium data being flagged "J" as estimated. Manganese and zinc concentrations were > 5 times the CRDL so RPDs were calculated.
4/2/99	PM-MW1 PM-MW2 PM-MW3 PM-MW6 PM-W1 PM-W3 PM-W6	Dissolved Copper Zinc	Field Duplicate	±CRDL (25 ppb) ±CRDL (20 ppb)	82.7 ppb 94 ppb	J	Because samples were #5 times the IDL for copper and zinc, the normal precision control limit of #35% RPD did not apply. An alternative control limit of ± CRDL were applied and resulted in the copper and zinc data being flagged "J" as estimated.
5/5/99	PM-MW1 PM-MW2 PM-MW6 PM-W6	Dissolved Cadmium	Field Blank	No significant contamination, #2x IDL or 9.6 ppb	36 ppb	U	Samples with less than 10 times the contamination concentration in the blank, but above the MDL should be flagged "U".
6/8/99	PM-MW1 PM-MW2 PM-MW3 PM-MW6 PM-W1 PM-W3 PM-W4 PM-W5 PM-W6 PM-W7	Dissolved Zinc	Field Blank	No significant contamination, CRDL or 20 ppb	1570 ppb	U	Samples with less than 10 times the contamination concentration in the blank but above the MDL should be flagged "U".

Date[1]	Sample ID	Analysis	QC Criteria	Control Limit	Result	Flag[2]	Comment
6/8/99	PM-MW1 PM-MW2 PM-MW3 PM-MW6 PM-W1 PM-W3 PM-W4 PM-W5 PM-W6 PM-W7	Dissolved Copper	Field Duplicate	±CRDL (25 ppb)	120 ppb	J	Because samples were #5 times the IDL for copper and zinc, the normal precision control limit of #35% RPD did not apply. An alternative control limit of ± CRDL was applied and resulted in the copper data being flagged "J" as estimated.
7/12/99	PM-MW1 PM-MW2 PM-MW3 PM-MW6 PM-W1 PM-W3 PM-W4 PM-W5 PM-W6	Dissolved Cadmium Dissolved Zinc	Field Blank	No significant contamination, 2 x IDL or 9.6 ppb No significant contamination, CRDL or 20 ppb	30.2 ppb 1640 ppb	U	Samples with less than 10 times the contamination concentration in the blank, but above the MDL should be flagged "U".
8/10/99	PM-MW1 PM-MW2 PM-MW3 PM-MW6 PM-W1 PM-W3 PM-W4 PM-W6	Dissolved Zinc	Field Blank	No significant contamination, CRDL or 20 ppb	809 ppb	U	Samples with less than 10 times the contamination concentration in the blank but above the MDL should be flagged "U".
2/15/00	PM-W1	Dissolved Zinc	Field Blank	No significant contamination, CRDL or 20 ppb	32.3 ppb	U	Samples with less than 10 times the contamination concentration in the blank but above the MDL should be flagged "U".

1 Date that the samples were collected.
2 Data Qualifier Definitions:
U-The material was analyzed for but was not detected above the level of the associated value (quantitation or detection limit).
J-The sample results are estimated.
R-The sample results are unusable.
UJ-The material was analyzed for but was not detected, and the associated value is estimated.

5. SUMMARY

All data from the field and HKM Laboratory have been validated according to EPA guidelines and the project-specific QAPP. Some of the data were flagged for out-of-control field blanks and field duplicates (see Table 3). The following recommendations are made for future MWTP projects.

- Ensure personnel are trained adequately to perform project specific measurements.

- Maintain consistency of personnel performing the sampling for a particular project to help ensure comparability. Seven different people in numerous combinations performed sampling for this project.

- The QAPP should have been revised when different techniques for critical flow rate measurements were used.

- Samples that are appropriate for laboratory internal QC checks can be designated to avoid having field blanks used for this purpose.

Appendix B

Peerless MWTP Mine View

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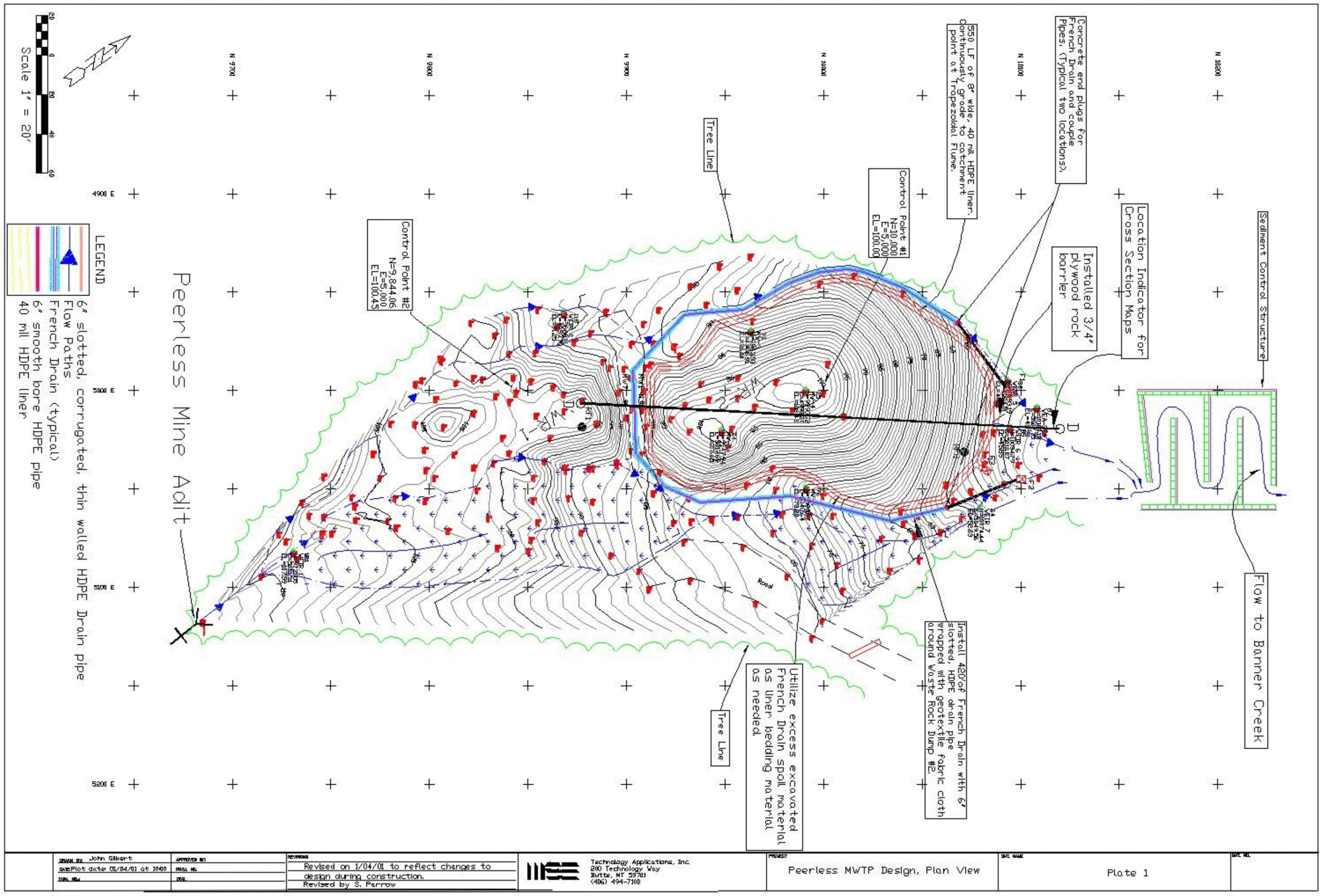

Appendix C

Peerless Mine Data